THE HAND

ITS MECHANISM AND VITAL ENDOWMENTS, AS EVINCING DESIGN.

BY SIR CHARLES BELL

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Seventh Edition, Revised.

PRECEDED BY AN ACCOUNT OF THE AUTHOR'S DISCOVERIES ON THE NERVOUS SYSTEM,

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PREFACE.

When one has to maintain an argument, he will be listened to more willingly if he is known to be unbiassed, and to express his natural sentiments. The reflections contained in these pages have not been suggested by the occasion of the Bridgewater Treatises, but arose, long ago, in a course of study directed to other objects. An anatomical teacher, himself aware of the higher bearings of his science, can hardly neglect the opportunity which the demonstrations before him afford, of making an impression upon the minds of those young men who, for the most part, receive the elements of their professional education from him; and he is naturally led to indulge in such trains of reflection as will be found in this essay.

So far back as the year 1813, the late excellent vicar of Kensington, Mr Rennell, attended the author's lectures, and found him engaged in maintaining the principles of the English school of Physiology, and in exposing the futility of the opinions of those French philosophers and physiologists, who represented life as the mere physical result of certain combinations and actions of parts, by them termed Organisation.

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That gentleman thought the subject admitted of an argument which it became him to use, in his office of "Christian Advocate."* This will show the reader that the sentiments and the views, which a sense of duty to the young men about him induced the author to deliver, and which Mr Rennell heard only by accident, arose naturally out of those studies.

It was at the desire of the Lord Chancellor Brougham that the author wrote the essay on "Animal Mechanics;" and it was probably from a belief that the author felt the importance of the subjects touched upon in that essay, that his Lordship was led to do him the further honour of asking him to join with him in illustrating the "Natural Theology" of Dr Paley.

That request was especially important, as showing that the *conclusions to which the author had arrived were not the* peculiar or accidental suggestions of professional feeling, nor of solitary study, which is so apt to lead to enthusiasm; but that the powerful and masculine mind of Lord Brougham was directed to the same objects; that he, who in early life was distinguished for his successful prosecution of science, and who has never forgotten her interests amidst the most arduous and active duties of his high station, encouraged and partook of these sentiments.

Thus, from at first maintaining that design and benevolence were everywhere visible in the natural world, circumstances have gradually drawn the author to support these opinions more ostentatiously and elaborately than was his original wish.

The subject which he has to illustrate in this volume, belongs to no definite department; and is intermediate between those

An office in the University of Cambridge.

sciences which have been assigned to others. The conception which he has formed of its execution is, that setting out as from a single point, he should enlarge his survey, and show the extent of the circle, and the variety of subjects, upon which it bears; thence deducing the conclusion, that as there is a relation of one part to the whole, there must be a system, and universal design.

The author cannot conceal from himself the disadvantages to which he is exposed in coming before the public, not only with a work in some measure extra-professional, but with associates distinguished by classical elegance of style, as well as by science. He must entreat the reader to remember that he was, early and long, devoted to the study of anatomy; and with a feeling (right or wrong) that it surpassed all others in interest and usefulness. This made him negligent of acquirements which would have better fitted him for the honourable association in which he has been placed: and no one can feel more deeply that the suggestions which occur in the intervals of an active professional life must always be unfavourably contrasted with what comes of the learned leisure of a College.

The author has to acknowledge his obligations to His Grace the Archbishop of Canterbury, the Bishop of London, and the late President of the Royal Society, for having assigned to him a task of so much interest. When he undertook it, he thought only of the pleasure of pursuing these investigations, and perhaps too little of what the public were entitled to expect from an Essay composed in circumstances so peculiar, and forming a part in this "great argument."

Brook Street, 1832.

NOTE.—The fourth edition of this Treatise was the last revised by the Author himself. In that which followed, upon permission having been kindly granted, some extracts were introduced from the two works noticed in the Preface. These are marked by being contained within brackets. To the present edition there has been prefixed a general Account of the Author's Discoveries in the Nervous System.

ALEXANDER SHAW.

CAVENDISH SQUARE, 1860.

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AN

ACCOUNT OF THE AUTHOR'S DISCOVERIES

IN

THE NERVOUS SYSTEM.

By ALEXANDER SHAW.

In the following Treatise, especially in the fifth and seventh Chapters, and the Appendix, there is frequent reference to the distinct qualities of the Nerves, in illustration of the properties of the Hand. But the Author has only alluded distantly to the original inquiries which he himself pursued in the Nervous System. The Discoveries for which Physiology is indebted to him, in that branch, are among the most valuable that have at any time been made. In the fundamental changes they have wrought on the theories held upon the subject, they are on a par with the Discovery of the Circulation of the Blood by Harvey. It may, therefore, be an appropriate introduction to this Volume, to give a brief account of the principal results of his researches.

When the author commenced his investigations, the subject of the functions of the Brain and Nerves was involved in great darkness. The extent of ignorance may be judged of, when it is stated that the distinction between the nerve which gives Motor power to the muscles, and the nerve which conveys Sensation from the skin, had not at that time been ascertained,

The opinion universally held was, that the nerves generally, to whatever part of the body they were distributed, possessed not only those two properties, but various other less clearly-defined ones; all of which, it was supposed, were obtained promiscuously from the brain, which was regarded as a common central source of every imaginable nervous endowment. And we may perceive that those who held that view, of motor power and sensation belonging conjointly to the same nerve, did not consider it impossible for two kinds of nervous influence, essentially distinct from each other, to be conveyed along its fibrils, one taking one direction, and the other a direction exactly opposite, at the same instant; for it cannot be doubted that the nervous agency which excites the muscles proceeds outwardly from the brain, or centrifugally; while that which communicates sensation proceeds inwardly, or centripetally.

We may be surprised that a view which appears now so incongruous should have held its ground so long. Yet there is a fact which will assist in accounting for the error. The body generally, from head to foot, is supplied, with scarcely an exception, by the extensive series of "Spinal nerves." Now, it happens that every one of that numerous class possesses the power of bestowing both motion and sensation. For example, if any nerve whatever that goes to the arm or leg be cut across, the immediate effect will be total loss of both functions in the part corresponding to the distribution of the nerve. Accordingly, when physiologists observed the same effects constantly produced by such experiments, they naturally concluded that the two properties were inseparably united in every nerve.

As an additional source of deception, it may be mentioned, that if a nerve be removed from the body, and its internal structure carefully examined, the thread-like fibrils of which it is composed will all appear exactly alike; nothing will be found in their size, colour, or texture, to indicate that there should be any difference in their functions.

It is to the author that physiology is indebted for the overthrow of those erroneous opinions, and for the discovery of the true principle on which the functions of the nervous system are to be investigated. To him the honour is exclusively due of having demonstrated, for the first time, that the nerve of Motion is distinct from the nerve of Sensation; and that when a nerve,

apparently simple, possesses both properties, it is a sign that it is really compound, and consists of fibrils derived from distinct divisions of the brain or spinal cord.

The process of investigation by which he made that pre-eminently great discovery may be briefly explained. It commenced in his adopting certain original views concerning the functions of the principal centres of the nervous system. He opposed the prevalent opinion, that the same common properties belonged indiscriminately to all parts of the Brain and Spinal cord. He conceived that, however undefined and irregular were the various subdivisions of these important organs, and however assimilated in structure, so as apparently to forbid the notion of their having any essential differences between them, they were, in fact, centres of distinct kinds of nervous *agency; but that all were subject to a connecting and presiding* influence exercised by the Brain as a whole.

Now, from this theory, of inferior organs, each endowed with a distinct power, being contained within the brain and spinal cord, the author was led to take a corresponding new view of the functions of the nerves. He conceived that each of those nerves which arose from a distinct organ, would possess the power of conveying to or from the body the particular influence with which the organ itself was endowed.

Accordingly, a method of ascertaining the functions of the nerves, never before thought of by physiologists, was suggested to his mind. Heretofore, the only attempts made to distinguish their uses had been by performing experiments on the trunks of the nerves at a distance from their origins, and where they had formed frequent connexions, in their course, with numerous others coming from totally different parts of the brain. But the mode he adopted, and which was the key to all his discoveries, was that of examining the nerves *at their roots*—close, that is to say, to the divisions of the brain, or of the spinal cord, from which they took their rise.*

The first nerves to which he applied that original method of research were those just adverted to as conferring motion and sensation conjointly, viz., the Spinal nerves. After a time, he carried his inquiries into the nerves of the Brain; and prosecuted them in a similar manner, by taking their origins as his

* Idea of a New Anatomy of the Brain. 1811.

guides. By thus extending his observations to both these organs, he gained the important advantage of comparing with each other various nerves which differed essentially in the number and structure of their roots, and of elucidating the functions of the one kind by contrast with the others.

If a Spinal nerve be taken anywhere in its course through the body, and traced backwards to its source in the Spinal cord, it will be found that, when it gets near the organ, it splits into two sets of fibrils, of equal size, called its "roots." On further examination, each root will be seen to dip into a division of the cord, circumscribed by distinct boundaries, termed a "column." One of these columns being situated at the back of the organ, the root connected with it obtains the name "posterior;" and a rounded body, of a reddish hue, called a "*ganglion*," is formed upon this posterior root. The fibrils of the other root are directed forwards and lost in the substance of a column situated in front, whence it is called "anterior;" and is distinguished from its fellow in not having a ganglion.

Encouraged by the observation of these marked differences in the roots to suppose that his theory was well founded, and that the one would be found to have a distinct function from the other, he felt justified in putting his views to the test of experiment, by exposing the spinal cord with its roots in a living animal, and dividing or irritating them, in succession. Accordingly he proceeded to perform that operation; and the results realised his anticipations. They proved decidedly that the "*anterior" root was distinct in its functions from the "posterior.*"

But here it must be stated that the author was not satisfied to rest his conclusions upon the particular functions of these roots on experiments confined to them alone. His final views were formed by associating the results obtained through them with others derived from experiments, presently to be described, on the nerves of the Brain.

The principal fact in regard to the spinal nerves, which he was sure of having fully established, was that the power of giving motion is exclusively the property of the "anterior" roots. Each time these were pinched, a convulsive action of those muscles which correspond to the distribution of the nerves experimented upon took place, leaving no doubt of the cause of

the movement: but a similar effect could not be produced by any amount of irritation applied to the "posterior" roots.

It might have been thought that when the author had thus decidedly shown that the "anterior" roots bestowed motor power, he would have concluded at once that the remaining function of the nerves, sensation, belonged to the "posterior" roots. But such was not his course of proceeding. He was convinced, that for determining the seat of a power of the nature of sensation, direct experiments on the roots themselves could not alone be depended upon. To comprehend the grounds of his want of confidence, we have merely to reflect on the peculiar character of the experiments. Necessarily, they are of a violent and painful description. They involve, first, the making of long and deep incisions through the skin and muscles of the back; the next proceeding is that of forcibly breaking into the narrow bony canal situated in the centre of the vertebral column; lastly, to expose the spinal cord and roots, the membranous sheath which immediately invests them has to be extensively opened. Now, the unavoidable consequence of all that severe operation is, that the animal, the subject of it, is stunned, stupefied, and terrified. It is, therefore, in a condition altogether unfit for drawing distinctions as to its capacity of feeling, or not feeling, in connexion with manipulations made by the experimenter on the particular roots at the depth of the wound. Accordingly, before the author drew his final conclusion concerning the function of the "posterior" root—which was decidedly that it conferred sensation—he had sought for and obtained evidence of a perfectly reliable kind to confirm its truth; his judgment was principally based on corroborative proofs derived from experiments on nerves of the Brain, next to be described.

When he proceeded to investigate the nerves of the Brain, his attention was directed chiefly to the two nerves which have the most extensive distribution of any in the head, viz., the "Portio-dura" and the "Fifth."

Before describing the experiments made on these two nerves, a brief account of the structure of the roots of each must be given; when it will be perceived that it would not have been possible to have selected from the whole body any other nerves better calculated to prove the soundness of his theory, and to

demonstrate the distinction between the nerves of motion and sensation.

The Portio-dura is distinguished for its arising from the brain, in remarkable contrast with the spinal nerves, by a single root alone. In common with a series of other nerves, (to which I shall presently refer,) it comes off from a circumscribed portion of the base of the brain, by a root upon which there is no ganglion. Having pierced the skull, it emerges on the face, in front of the external ear, and lies there almost directly under the skin. During its course it forms no important connexion with any other nerve, so that it is as simple in its anatomical structure at that part as when it had just arisen from the brain. The nerve now subdivides into numerous branches: these take a leap, as it were, across a particular class of muscles, those of the jaws, to avoid them; and they are eventually distributed, in the fore-part of the face, to the muscles which move the features.

The Fifth is characterised by being the only nerve among those of the brain which arises, like the spinal nerves, by two distinct roots, each from an appropriate part of the organ; and not only are its roots double, but upon one of them is formed a "ganglion" exactly like the body of the same name on the posterior roots of the nerves of the spine. Yet, although the analogy here indicated cannot be doubted, a difference is to be observed in the roots of the Fifth, which adds much to the interest of examining its functions. In the spinal nerves, without exception, the two roots are of equal dimensions; consequently, all the branches consist of the same number of fibrils of each, and no distinction can be drawn between them. But in the Fifth, the root upon which the ganglion is formed is fully five times greater in size than the one which has no ganglion. Hence it follows that, in the distribution of the branches of the whole nerve, a large proportion belong exclusively to the "ganglionic" root, and a few only are composed of the two roots joined together. It is also observed that the branches prolonged directly and simply from the large root, course to all the surfaces of the head,—the skin and sensitive membranes, where no muscles exist,—while those which contain the fibrils of the lesser root can be traced to the group of muscles which the Portio-dura had passed by, viz., the muscles of the jaws.

The experiments performed by the author on the Portio-dura, which goes to the features, were in their results most decisive. To expose the nerve, he had to make only a small incision, scarcely larger than that for venesection; and when he cut it across, the effect was instantly visible. All the muscles corresponding to the distribution of the nerve were at once arrested in their motion—paralysed; but the sensibility of the skin was not in the smallest degree impaired. Among other animals on which he performed the experiment was the monkey; selected on account of the mobility and activity of his features. Before the operation, the creature was, of course, full of grinnings and grimaces at the liberties taken with him: the moment that the Portio-dura was severed, although his anger and jabberings did not cease, his face became passive and expressionless, like a mask. It was thus incontestibly proved that the only function with which this nerve is endowed, is the power of giving motion to the muscles.

The experiments which he next undertook were upon the Fifth. And he chose, first, those branches that emerge upon the face, at three distinct points, to supply the same parts to which the Portio-dura is sent. Although he doubtlessly perceived that, as motor power simply was conferred by that nerve, the remaining function, sensation, would, almost certainly, be bestowed by the only other distributed to the part, the Fifth, yet he subjected the branches to the necessary experiments.

These branches have a particular interest attached to them, from the mode of their origin. Each comes off directly from the large, ganglionic root; and each pursues its course to its appropriate part of the face, without forming a connexion with any other nerve. The individual branches are, therefore, true representatives of the root from which they arise. Again, when they arrive at their destinations, they are situated quite superficially, being covered alone by skin; and they can be exposed for experiment with the utmost facility. Accordingly, experiments performed on these branches are essentially the same in value for determining the function of the ganglionic root, as if they had been made directly upon the root itself within the cranium.

When these branches were cut across in a living animal, the result expected was obtained. It was shown that their property

was to bestow sensation; and that, in correspondence with their arising simply from the single root, the "ganglionic," they had no other function, and could not give motor power. When divided, the skin of the animal could be freely pinched and pricked without drawing forth any signs of feeling or pain. Yet, although the part appeared thus dead, the movements were not in the smallest degree directly affected: they were preserved through the influence of the Portio-dura, which was entire.

The experiments now remaining to be performed were upon those branches of the Fifth which are composed of the lesser, "non-ganglionic" root, combined with some fibrils of the larger root, and which are distributed wholly to the muscles of the jaws. When these compound branches were cut across in a living animal, two effects were instantly produced: first, sensation was destroyed in the surfaces to which the fibrils of the larger root were distributed; secondly, all power of motion was immediately lost in the muscles of mastication. The jaw-bone dropped, and could not be raised to bring the teeth together. When the cut ends of the nerve were pinched by forceps, the paralysed muscles acted with spasmodic suddenness; the jaw closed with a snap; and the fingers of the incautious assistant being between the teeth, received a sharp bite.

The name which the author chose for expressing the double nature of the functions of the Fifth, and the peculiar appropriation of its motor root, was the "Nerve of Sensation and Mastication."

By these joint experiments on the two nerves of the brain, the Portio-dura and Fifth, every proof that could be required was furnished to demonstrate, in the most satisfactory manner, that the nerves of motion are distinct from those of sensation; that the distinction bears direct relation to the roots by which they arise respectively from the brain; and that when a nerve is found to possess both functions conjointly, it is a sign that it is really double in structure—composed of fibrils, one set of which come from an appropriate part of the brain that bestows motion, and the other from a different part that confers sensation.

It now rests with me only to point the reader's attention to the value of the observations on the two nerves of the brain just described, in elucidating what was obscure regarding the func-

tions of the roots of the Spinal nerves. By the experiments on the latter, it was indisputably shown that the "anterior" roots were those which bestowed motor power. It was also observed that they were destitute of ganglions: and as both the Portio-dura, proved experimentally to be a nerve of motion, and the lesser root of the Fifth, likewise proved to give motor power, were unprovided with ganglions, it was seen to be characteristic of nerves of motion that they should be without these appendages. Again, as to the "posterior" roots, on which the ganglions are formed, it has been said that, owing to the violence unavoidably inflicted in experimenting on the Spinal nerves, evidence to be relied on could not be obtained to prove that these were the roots of Sensation. But when the experiments on the roots of the Fifth showed, in an unerring manner, that the smaller, non-ganglionic root, analogous to the anterior roots of the Spinal nerves, gave motor power alone, and that the larger, ganglionic root, analogous to the posterior roots, bestowed sensation, all doubt on the matter was removed; it was concluded, most decidedly, that the function of the posterior roots of the Spinal nerves was to confer Sensation.

GENERAL CLASSIFICATION OF THE NERVES.

Having succeeded in establishing on a firm foundation the important physiological truth—That the nerves of Motion are distinct from those of Sensation—the author had made a most valuable advance in our knowledge of the nervous system. But he did not cease his labours at that point. By surveying the nerves of the body generally, and observing the different modes in which they arose from the subdivisions of the brain and spinal cord, on the one hand, and the appropriation of particular kinds of nerves to distinct organs, on the other, he was led to believe that such peculiarities of origin and distribution had an important significance,—that they indicated distinctions in the functions of the nerves additional to those which he had already ascertained.

In taking that extended view, two principal objects attracted his notice,—First, he was particularly struck by the remarkable manner in which the large series of Spinal nerves, with their

analogous nerve of the brain, the Fifth, arose from the central organs, and passed to their destinations; secondly, by the mode in which another series, comparatively small, and formerly adverted to as represented by the Portio-dura, came off from a limited portion of the brain, and was distributed to its appropriate parts.

Attending to the series of Spinal nerves and Fifth. The chief distinguishing characters of these nerves were, first, that they all arose from the spinal cord and brain by two distinct roots,—one of motion, the other of sensation. Secondly, that, with an exception to be noticed presently, they were distributed generally and promiscuously over the whole body. Thus, with the reservation alluded to, these combined nerves furnished to all members and regions of the frame the two properties most essential for a nervous system to give. They bestowed Sensation on the integuments and every other sensitive surface from the crown of the head to the sole of the foot, together with Taste: they gave also motor power to the trunk, the neck, and the upper and lower extremities. But here the exception must be specified. It relates to the power of the Fifth in giving motion. That nerve distributes its branches which bestow sensation freely and without bounds to every part, internal and external, of all the head; but as a motor nerve, it is confined exclusively to particular muscles—to those which move the jaw in the act of *Mastication.* The author, as already stated, had applied to it the name, Nerve of Sensation and Mastication. Accordingly, the general character to be assigned to the series of Spinal nerves and Fifth was, first, that they bestowed Sensation or Touch over the whole extent of the body, without limit, and the sense of Taste in addition; secondly, that they bestowed Motor power, also without limit, upon every region and member of the frame apart from the head, and upon the muscles of mastication exclusively, in the head.

Next, attending to the smaller series of nerves, observed to be opposed in various respects to those just mentioned. The characters which chiefly distinguished them were, first, that they arose, by single roots, from a defined and limited portion of the brain, near its junction with the spinal cord, and were capable of bestowing motor power alone; secondly, that they were distributed solely to a particular region of the body, in-

cluding the face, throat, neck, and chest. Again, it was remarked that, instead of coursing to their respective destinations, like the Spinal nerves and Fifth, in a symmetrical manner, by the shortest and straightest route, those nerves proceeded in a devious and divergent way, crossing the paths of the others, and terminating in organs already supplied with nerves. In reference to the Portio-dura, the most conspicuous of them, some peculiarities of a special kind were noticed. The principal was the exclusiveness of its distribution to those muscles of the face which move the *Features*. To reach these, the nerve takes a long, winding route from behind: after emerging in front of the ear, it is in close proximity to the muscles of the jaws, and actually lies for a considerable part of its course upon two of the largest; but it declines sending a single branch to these muscles: it pursues its way across them, undiminished in size, to the muscles of the features beyond. Again, it is remarkable that these muscles, to which the Portio-dura thus goes circuitously, have large branches of the Fifth, not less than three on each side, distributed freely in the midst of them; but they come off from the ganglionic root alone, have no fibrils of the motor root joined to them, and bestow sensation exclusively. Accordingly, the peculiarities of the Portio-dura may be summed up by saying, that it avoids contributing branches, which it could easily have done, to the muscles of the jaws, and exhausts itself altogether on the muscles of the features.

These were the observations which led the author to believe that some important distinctions would be found to exist between the two series of nerves whose peculiarities have been thus shortly set forth. The theory which he advanced to solve the problems it will be my endeavour to lay before the reader, in as brief a space as can be done. And I may premise by stating that it involved an examination of the development of the Nervous System through the whole members of the animal kingdom.

First, the author conceived that a class, formed of the Spinal nerves and Fifth, and to which he applied the term "Original System," ministered to organs, and bestowed nervous endowments, essential for the existence and well-being of creatures of

every grade, high and low, in the animal kingdom. Secondly, that an additional class, of which the Portio-dura was a type, and to which he gave the name "Respiratory System," was needed only by those animals, near or at the summit of the scale, in which the organ of Respiration had become adapted, by successive changes of structure, to be the instrument of Voice, and, in Man, also of Speech and Expression.

Original System of Nerves.

I. It has just been said that the author conceived that the Spinal nerves and Fifth were the representatives, in the higher animals and man, of a class common to them and to all below them—a class which ministered to functions and endowments required equally by animals in general. The mode in which he endeavoured to establish that view was the following. He sought, in the first place, to ascertain the primary objects for which, in the construction of an animal, a nervous system was originally demanded; and in the next place, having satisfied himself concerning that point, to learn whether these objects could be secured, or the necessary functions of an animal be provided for, by a class of nerves furnished with the powers that belong to the Spinal nerves and Fifth.

In order to learn what may be the requirements, in animals generally, which make the introduction of a nervous system into their bodies necessary, he directed his observations to the contrast between members of the Vegetable kingdom, which are destitute of a nervous system, and those of the Animal kingdom, in which it first appears. It is a well-known fact in zoology, that the transition between beings of the two kingdoms is so gradual, that it has always been a source of dispute, in treating of those which reside on the confines, whether particular individuals were the subjects of the one or of the other realm. But looking on the subject differently, the question may be properly asked—What are the generally-pervading characters of a Vegetable, viewed in the abstract, as contrasted with those of an Animal, viewed similarly in the abstract?

Now, the cardinal difference between the Vegetable, on the

one hand, and the Animal on the other, is, that the former is a *stationary organism*, the latter *locomotive*. In other words, the vegetable obtains its nourishment and lives by means of roots which bind it prisoner to one place; the animal has to shift its locality, seize its food, and, after due preparation in the mouth, convey it into the interior of its body. When the aliment has been swallowed, it is true that the processes of assimilation, and of otherwise dealing with it, are analogous. But the characteristic distinction between them remains—that the one is fixed, the other moveable.

Accordingly, a new question arises :—An organised body, dependent for its subsistence on nourishment which it must procure by voluntarily going in quest of it, being given, what organs and properties must it possess to qualify it for that mode of existence?

The following series of parts appears indispensable :—

First :—Organs of Locomotion—including all varieties of instruments by which animals can change their localities—as Legs, or inferior substitutes for them.

Secondly :—Organs of Prehension—including all varieties of instruments by which animals can seize and secure their prey, or other food—as Arms and Hands, or inferior substitutes for them.

Thirdly :—Organs of Mastication—including all varieties of instruments by which animals can triturate, and reduce the food to a fit condition for being swallowed and conveyed into the stomach—as Jaws armed with Teeth, or their inferior substitutes.

All the above instruments are specially characteristic of Animal, as contrasted with vegetable organisation. Each also may be conceived to exist as an independent structure. *But owing to the variety of positions, habits, and instincts* of animals, and their obtaining nourishment from infinitely diversified sources, the different organs present themselves in the most multifarious forms. In animals lowest in the scale, slightly removed from vegetables, the instruments are so fused, by mutual interchange of offices, into one another, that it is difficult to recognise the identity of each: the prehensile organ will be found acting in aid of the locomotive, and the manducatory, it may be, in combination with both. But as animals progressively rise in the scale, a gradual departure from that

community of office is observed; each organ becomes disembarrassed of the duties of the others, and performs its own particular function alone. At length, when the animal organisation has reached its highest point of development in Man, we find Locomotion executed exclusively by its appropriate members—the Lower Extremities: Prehension executed exclusively by its appropriate members—the Upper Extremities: and Mastication by its appropriate instruments—Jaws and Teeth.

And here it may be observed, that, when the Lower Extremities, by their perfect construction as implements of locomotion, have emancipated the Upper Extremities from sharing in progression, so that the Hand and Arm are independent, and available for all acts of prehension, the Jaws and Teeth cease to be employed for seizing and holding. The mouth is exempt from performing any other duty but that of Mastication. Consequently, the bones of the face, jaws, and teeth admit of being reduced in dimensions: and the cavity of the mouth adapted, in size and form, to be an important part of the organ of Voice and Speech, in relation to man's highest endowment—his Mind.

Such being the association of organs necessary for the construction of an Animal, viewed in the abstract, the question next arises—How is the mechanism to be animated; or, what must be the combined properties of a Nervous System, designed to meet the wants of the organism? By following that inquiry, we may be led to ascertain what is the most elementary form of a System of Nerves.

In the simplest view that can be taken of a nervous system, we must suppose the existence, in some part of it, of a central organ, corresponding to the Brain in the highest animals; an organ *from* which motor power may be transmitted to the muscles, and *to* which one or more senses may be conveyed from the surface. It is also reasonable to assume, however difficult it may be to prove the fact anatomically, that in the elementary brain the particular structure which initiates motor influence will be different from that which receives impressions from the senses.

With the doubly-constituted organ thus introduced, it must be supposed that nerves will be provided as media of communication—one set for giving Motion, and the other for giving

Sense. Two questions therefore present themselves, bearing directly on the immediate subject of the inquiry—What will be the particular nerves of motion ; and What those of sense?

The answer in regard to the nerves of Motion is simple. Nerves of that kind will require to be allotted to the various organs enumerated as composing the frame of the animal. First, they will be sent to the Locomotive organs, represented in man by the Lower Extremities; next they will be sent to the Prehensile organs, represented by the Upper Extremities; and lastly, to the Manducatory organ, represented by the Jaws and Teeth.

As to the nerves of Sense. It is reasonable to suppose that, of all the senses known to belong to animals generally, that of Touch, or common Sensation, extending over the whole body, will be the most essential for a creature placed lowest in the ranks of the animal kingdom. And the next sense in importance will be that of Taste, the guardian of the opening by which food is passed into the stomach.

It will now be perceived, that, by following this course of observation, and imagining an Animal, of the simplest form, having the fewest attributes consistent with its ranking above Vegetables, we arrive at the conception of a system of nerves, which, for the properties supposed to belong to it, agrees precisely with the class of Spinal nerves and Fifth, in the higher animals and Man. By the former extensive series—the nerves of the spine—power of motion is given to the upper and to the lower extremities, the representatives of the organs of Prehension and of Locomotion; and by the small root of the Fifth, distributed exclusively to the muscles of the jaws, motor power is bestowed on the part which represents the organ of Mastication. Again, by the Spinal nerves, common Sensation or the sense of Touch is supplied to all the surfaces of the body (except the head); and by the large root of the Fifth, the same property, Touch, is given to the whole head, together with the special sense of Taste.

The conclusion, therefore, to which the author came was, that the series of Spinal nerves and Fifth constituted a class which belonged to animals in all grades of the animal kingdom; that it ministered to functions and endowments equally necessary to those high and low in the scale; that in animals of earliest and

simplest construction, it existed in the rudimentary form of a nervous system; but that, by a gradual process of development, it attained the perfect condition exhibited in the Vertebrata, and in Man. Wherefore, in arranging the series together in his classification, he applied to them the name "Original" system of nerves.

Respiratory System of Nerves.

II. The nerves next claiming attention are those which, we have seen, are distinguished by arising, in limited number, from a small circumscribed portion of the base of the brain, by single roots, and which diverge, in an apparently irregular and scattered manner, across the other nerves, to be distributed to the face, throat, neck, and chest—that is, to the region where the organ of Respiration, with its concomitant parts, is situated.

The fact that these nerves seek the organ of breathing for their destination, naturally induced the author to study closely all relating to that part of the body, in the hope of obtaining facts which might assist in his inquiry. In that manner he was eventually led to examine with peculiar interest a series of extensive changes which gradually takes place in the scheme and uses of the apparatus, during its development from the lowest to the highest animals.

The organ of respiration, in the language of physiologists, is commonly understood to refer only to that structure in animals which is designed to expose the blood to the influence of the air, so that the vital fluid may be purified and rendered fit to circulate over the body. But essential as that office is to all living beings, and a similar process of aërating and renovating the fluids is carried on in vegetables as well as animals, it is not to be regarded as the most elevated application of the organ. Without diminution of its efficiency in that capacity, the mechanism is adapted, in Man, to an object altogether foreign to its original use: the structure is so ordered and arranged that the air, which has been employed in oxygenating the blood, is utilised, in the act of being expelled from the body, to produce audible sounds—the elements of Human Voice and Speech.

The addition to the organ of respiration of that high office,

connected with Man's noblest endowment, the Mind, is effected, in the course of its gradual development through the animal kingdom, by a series of changes successively made in its construction. As it belongs directly to our subject to examine these, I propose to give a general view of them, by tracing the mechanism, with its various modifications, through the different grades of animals, from the lowest to the highest.

First, it is important to notice that the process of respiration is conducted in animals on two widely distinct plans. One of these is termed the "Diffuse;" the other, the "Concentrated" system.

By the Diffuse system, is meant that mode of breathing by which the air, or the water charged with air, is brought in proximity to the blood by playing on surfaces upon which the vital fluid circulates more or less abundantly, but which surfaces are open and unenclosed. Here, then, is the distinctive peculiarity of the method—that the air made use of is not confined within a cavity. When it has performed its office, it is dispersed and lost.

In the Concentrated plan, the chief characteristic is the introduction into the mechanism of a membranous sac, capable of holding air; and of a tube, which communicates with the external atmosphere. The blood to be aërated circulates on the surface of the air-sac: and the air can be constantly changed, by the alternate expansion and compression of the walls surrounding the sac. From that general description it will be perceived that the sac containing air is the representative of lungs; the tube, of windpipe; and the enveloping walls, of thorax. It will also be seen that in an apparatus consisting of such parts, elements are supplied for the formation of an organ of Voice. It only requires that the air confined in the bag shall be expelled along the pipe, with a force sufficiently great to cause the special vibrations of sound, that it may be applied to that office.

Next, of the animals to which each of these distinct modes of respiration belongs. In arranging the animal kingdom, the most comprehensive division is into the two great sub-kingdoms—the Vertebrata, and the Invertebrata. Now, it is an interesting fact, in connexion with our subject, that in the whole extent of the lower of these divisions, there is not a single example of an animal which breathes according to the Concen-

trated system: the only method is the Diffuse. That is equivalent to saying that in no animal of the Invertebrate sub-kingdom, is the mechanism formed on a plan consistent with its producing sounds adequate for Voice.

It is not till we mount up to that high stage in the animal kingdom, where animals begin to be formed on the Vertebral type, that breathing by the Concentrated method is met with. We then, for the first time, perceive introduced into the animal framework, an apparatus analogous to thorax, lungs, and windpipe. In the inferior classes of the sub-kingdom, we see, and that obscurely, only the elementary rudiments of the construction. But by degrees, and in proportion as animals approximate in their general structure to Man, the mechanism becomes better calculated for performing its double office,—first, of purifying the blood; secondly, of ministering to Voice.

I may now point out, in a general manner, the more prominent *changes wrought upon the organ, during its course of* development through the five different classes of Vertebrata.

1. In Fishes, which form the lowest class of Vertebrata, the organ of respiration exhibits a transition state between the Diffuse and the Concentrated systems. The gills are constructed according to the former plan; yet the process of taking in the water by the Mouth, that it may be swept over the gills, is according to the latter. Indeed, the employment of the mouth in connexion with the operation of breathing, which is general in all the Vertebrata, *is altogether unknown in the Invertebrata.* In the latter, the oral orifice has relation exclusively to the digestive functions. The first time, in the animal kingdom, that the mouth is found to serve the double purpose of being a cavity for receiving food for the stomach, and an opening for the passage of the air in the vital operation of breathing, is in Fishes.

But it is not the gills which, in this class, claim principal interest in reference to the development of the organ of respiration. In certain fishes, there are lodged, within that part which corresponds most nearly to their chest, a membranous sac, and a tube; and these are the true first representatives, in animals, of Lungs and a Trachea. Disguised by performing an office not directly connected with breathing, they are not easily recognised as having any relation to that organ. The sac is filled

with air, and it forms what is called the "Swimming Bladder," by the expansion or compression of which the fish can either diminish or increase its specific gravity in the water: the tube, when appended, opens at the back of the throat; in that respect it resembles a windpipe; and it obtains the name *ductus pneumaticus*.

2. The earliest example of the air-sac and tube, thus existing in a dormant state, as regards respiration, in the fish, being applied to breathing, is found in the class intermediate between them and reptiles, viz., Amphibia. These ichthyosaurians inhabit the margins of rivers and lakes, overflowed at one time, and dried up at others: they are, accordingly, bounteously supplied with both aquatic and terrestrial organs of breathing. Outside their bodies, they possess gills resembling those of fishes; and so long as their territory is submerged they make use of them. When the waters subside and they are stranded on dry ground, they take to the swimming bladder, or Lungs, within. Blood-vessels, conveying the impure blood, are freely distributed on that sac: and the animals have the power, by the expansion and contraction of the surrounding walls, or Thorax, of alternately filling it with air and emptying it again, through the pneumatic duct, or Trachea.

3. Except in the young of certain orders of the next class, Reptiles, the gills are entirely discarded; and respiration is performed exclusively according to the Concentrated system. But even in the most perfect, the mechanism of the organ is rude, corresponding to the animals of the class being cold-blooded. In the majority, the Lungs present the appearance of membranous sacs, or swimming bladders, rather than that of true pulmonic structure. Again, the Ribs forming the boundaries of the thorax are either too flexible, in accommodation to their characteristic mode of progression by creeping; or are too inflexible, from being embarrassed with remains of the external skeleton. But the most notable imperfection consists in the absence of a diaphragm, or the muscular partition which divides the thorax from the abdomen. The lungs and the bowels occupy a common cavity. It deserves, however, to be remarked that Nostrils are seen first in this class. These tubes being rigid, and permanently open, furnish a supplementary inlet for the air, when its entrance into the lungs might be interrupted by

obstructions in the mouth, during the act of eating. The nostrils provide also a suitable locality for the organ of Smelling.

4. In the class which comes next, that of Birds, the improvements observed in the organ relate principally to its use in decarbonising the blood. As these feathered animals are designed for flight, they are constructed to be extremely buoyant. That lightness is attained by the air which they respire being conducted by tubes and cells over their whole bodies; consequently, they have a disproportionately large quantity of air constantly passing through their lungs: the blood is, therefore, more perfectly aërated than in the animals below them; and they are warm-blooded. However, there is the same great want in them as in reptiles, that of a diaphragm. Nevertheless, Birds contribute to the sum of the improvements effected in the organ generally, by furnishing a true vocal organ; it is in them that we perceive the earliest appearance of a proper Larynx.

5. Ascending to the next class, Mammalia, we find carried out to its greatest perfection the principle of the system of Concentrated respiration. And that advancement is mainly due to the introduction into the formation of the chest of the Diaphragm; which is at once the means of confining the lungs, together with the heart, in a separate compartment, and of giving great additional force to the acts of breathing.

It is with this important stride in the process of development of the organ that we perceive, most distinctly, the fulfilment of the grand design of converting the apparatus of respiration into the instrument of Voice. By the thorax being now adapted to expand its cavity to a large extent in inspiration, and to contract it forcibly in expiration, it is capacitated to fill the lungs with air, on the one hand, and to expel it, on the other, in ample volumes, with a powerful impulse. Accordingly, the air, being thus forcibly expelled, can be thrown, in its passage through the larynx and mouth, into the special vibrations which produce varieties of Sounds.

It is interesting here to observe how new structures, which would have been useless had they been added to the organ at a previous stage of its development, are introduced in correspondence with its increased powers. I refer now to the Lips. These appendages of the mouth are first met with in Mammalia.

And the original use to which they are applied relates to the mode of rearing their young, which gives to animals of this class their particular designation. Lips are indispensable for suckling; and that act could not have been performed unless nostrils had been previously furnished, and unless the chest had been constructed so as to allow the young mammal to draw deep inspirations.

But a higher office awaits the Lips in Man. These fleshy fringes are essentially required to adapt the mouth for Voice and Articulate language. Lips are also important parts of the features of the Countenance; and they are, therefore, constituents of the principal organ by which feelings and emotions, too refined for speech, are made known—that of Expression.

And here an observation presses itself upon our notice, in reference to the influence which powerful emotions, as witnessed in Man, exercise upon the organ of respiration, including the countenance. No structures of the body performing different duties are more closely allied to each other than the Heart, the centre of the circulating system, and the organ of Breathing. Throughout the whole animal kingdom, the development of each proceeds with equal steps. But it belongs to our present subject to attend only to the relation between them in the highest animal, Man. When the organ of respiration assumes the Concentrated form, the heart becomes also a Concentrated organ. By that expression is meant that the chamber of the heart previously appropriated, in the inferior animals, as a distinct muscular cavity, to circulating the impure blood through the lungs, is incorporated in Man with the chamber which sends the blood, when purified, over the whole body; so that the two cavities compose together an united organ, divided only by a partition. Accordingly, a material sympathy is established between the "pulmonic" and "systemic" cavities: they relax and contract simultaneously. From that arrangement, it follows that blood is propelled from one side into the lungs, and from the other side into the system, at each beat of the heart. Hence, if a disturbance sufficient to interrupt the currents should occur, its effects will be manifested both in the organ of respiration and in the body generally. Now it is a fact, of which every man's feelings make him conscious, that when strong emotions affect the mind, the heart, the "bosom's lord," is correspondingly agitated. The consequence

is, *that a momentary interruption, or a temporary acceleration,* in the action of the heart is produced, accompanied with a sense of palpitation at the breast. In proportion as the blood is either hastened or retarded in its course to the body, particularly to the brain and skin, tremors, or paleness, or blushing will be observed: and according as it is driven to the lungs with undue impetuosity, or its flow is arrested, the breathing will be hurried, or slow, or alternate between the two states. Man is so constituted that he can interpret the changes to which these disturbances give rise. Prompted by a sympathetic sense, he reads instinctively, as a natural language, the signs of the troubled bosom in a fellow-man. And this mode of communication is intelligible to the inhabitants of every nation and clime, however diversified their articulate words. It is the language of Expression—a common link of all mankind.

Thus we perceive how, by a combination of extensive changes *gradually wrought in the structure of animals, from the lowest* to the highest, a fit instrument is at length constructed to minister to Man's highest endowment, the Mind. Following the development of one class of organs, we saw that, by the perfection attained in the structure of the instruments of Locomotion and Prehension in Man, the Mouth became freed from employing the jaws and teeth like the brutes; and that its cavity could, therefore, be reduced in size, the teeth set erect in close and uniform rows, and the whole form arranged and proportioned, for the articulation of words, in Speech. By following a parallel course of development in the organ of Respiration, we observed it constructed, in all the Invertebrata, on a plan inconsistent with its being applied at all to Voice. But in the Vertebrata, we saw the same organ gradually shaped and built up, by successive introductions of new structures, until it was converted into an instrument capable of propelling currents of vocalised air to the Mouth; thence to issue forth by the Lips, as articulate Words. If to Speech, thus wondrously provided, powerful emotion of the mind be conjoined, the organ will present itself in a new phase; words will be associated with the manifestations which that emotion creates in the body—Expression. When the Voice suffers interruption and falters, and the face, neck, and chest are animated by strong passion working from within the breast, human language exerts its most com-

manding *influence*. Then the organ is beheld in its highest condition of development.

Such was the extensive course of observation pursued by the author, in endeavouring to solve the problem, why, in the higher animals and Man, there should be provided to the organ of respiration, in addition *to the largely distributed class of double nerves*, the Spinal nerves and Fifth—another series, consisting of nerves with single roots, derived from a distinct division of the brain. These nerves he conceived to be a superadded class, introduced to preside over the organ of breathing when it had assumed, in the Vertebrata, the extraneous office of acting as an instrument of Voice. Having observed that, in the transition from a simple apparatus in which the air of respiration is applied exclusively to oxygenating the blood, to a complicated mechanism in which the same air is employed also for the production of vocal sounds, material changes, including the annexation of new supplementary parts, were made in the organ, he inferred that these changes would be accompanied with corresponding modifications in the nervous system. As the superadded structures were moved by muscles, and regulated by sympathies, he argued that they would require to be provided with appropriate nerves. But he further thought that a supply of new nerves alone would not suffice,—that it would be necessary that these nerves should have a centre of power seated in the brain and spinal cord. Hence he believed that, in conformity with the introduction of new portions of mechanism into the organ of breathing, there would be, not only an addition of appropriate nerves, but the development within the brain of a new division of its substance, endowed with influence over the nerves. Upon these grounds he concluded that the particular series of nerves which are characterised by being distributed to the organ of respiration, together with the portion of brain from which they arise, had been added, in the course of development of animals generally, to the pre-existing "Original" system of nerves. And on account of the relation they bear to the organ of breathing, he applied to them the name "Respiratory" system.

When the nerves included in the two foregoing classes—the "Original" and the "Respiratory"—had their respective places assigned in the arrangement, nearly every nerve throughout

the body which arises from the Brain and Spinal cord had been accounted for. The nerves not comprehended were merely those of the three organs of Sense—Smelling, Seeing, and Hearing—together with the few nerves of the orbit subservient to the appendages of the Eye.

In regard to the nerves of the, Senses, the author conceived that the particular sense possessed by each was a special and distinct endowment, and that it was obtained through the connexion of the nerve, at its root, with a part in the interior of the brain introduced to give that sense exclusively. Hence, he considered that no one nerve of sense could take upon itself the office of any of the others. For example, he did not think it possible that the nerve of Vision could feel by Touch; any more than that a nerve of Sensation could perceive variations of light or colour. The Optic nerve, he thought, was limited to discriminating diversities of colours or shades of light ; the Auditory to distinguishing varieties in sound; and so with the others. Several interesting illustrations of these views are given in the pages of this volume. Again, he was of opinion that each of the various senses was implanted in the nervous system, at a distinct stage in the development of animals generally. The senses of Touch and of Taste, as already said, he believed to be the first conferred. The others, he thought, were added successively, in proportion as animals rose in the scale, and stood in need of more varied sources of perception in regard to the properties of external objects. Entertaining these views, he represented the nerves of Smelling, Seeing, and Hearing as supplementary to those of Touch and Taste, constituting a sub-class of the "Original" system.

All the nerves embraced in the great Cerebro-Spinal axis—by which term is meant all that arise collectively from Brain and Spinal cord—having been thus disposed of in the author's classification, there remained to have an appropriate place allotted to them but one set of nerves, and the general characters of these differed so greatly from the others, that there could be no difficulty in classing them quite apart from the rest. The nerves referred to are those denominated by anatomists variously, the Sympathetic or Ganglionic system. The view which the author took of that series was determined principally by his

assuming that it fulfilled offices which had been left unprovided for by the classes of nerves whose functions had been ascertained. He supposed that it presided over those organic processes, in the economy, which are common to Vegetables and Animals, and which are carried on secretly and independently of the direct control of the brain—such as secretion, absorption, assimilation, growth, reproduction, decay.

THE HAND;

ITS MECHANISM AND VITAL ENDOWMENTS, AS EVINCING DESIGN.

CHAPTER I.

INTRODUCTORY.

If we select any object from the whole extent of animated nature, and contemplate it fully and in all its bearings, we shall certainly come to this conclusion: that there is Design in the mechanical construction, Benevolence in the endowments of the living properties, and that Good on the whole is the result. We shall perceive that the Sensibilities of the body have a relation to the qualities of things external, and that delicacy of texture is, therefore, a necessary part of its constitution: that wonderful, and exquisitely constructed as the mechanical appliances are for the protection of these delicate structures, they are altogether insufficient; that a protection of a very different kind, which shall animate the body to the utmost exertion, is requisite for safety: and that Pain, whilst it is a necessary contrast to its opposite pleasure, is the great safeguard of the frame. Finally, as to Man, we shall be led to infer that the pains and pleasures of mere bodily sense (with yet more benevolent design) carry him onward, through the development and improvement of the Mind, to higher aspirations.

To comprehend the perfection of the structure of any single organ of an animal body, and to see how the same system of parts is adapted to an infinite variety of conditions, we must view the same organ *comparatively:* this carries us into a new

science, no less than that which regards the changes in the surface of the Globe. And although, in this comparison, we shall find that stupendous revolutions have occurred indicative of power, it is in contemplating the adaptation of the newly-introduced forms of living and organised matter to these successive changes in the surface of the earth, that we shall have the best proofs of the continuance of that Power which first created.

Such is the course of reasoning which I propose to follow in giving an account of the Hand and Arm. I shall contrast them, in the first place, with the corresponding parts of living creatures through all the divisions of the chain of vertebrated animals; and then I shall take the hand, not merely as combining the perfections of mechanical structure, but as possessing the property of Touch, by which it ministers to and improves every other sense, constituting it the organ in the body the most remarkable for correspondence with Man's capacities.

Some may conceive that, as I have for my title the Human Hand and its relation to the other solid structures of the animal frame, it will lead me to consider the body as a *Machine* only. I neither see the necessity for this, nor do I acknowledge the danger of considering it in that light. I embark fearlessly in the investigation, convinced that, yielding to the current of thought, and giving the fullest scope to inquiry, there can be no hidden danger if the mind be free from vicious bias. I cannot see how scepticism should arise out of the contemplation of the structure and mechanism of the Animal Body.

Let us for a moment reflect what is the natural result of examining the human body as a piece of machinery; and see whether that makes the creation of man more or less important in relation to the Whole Scheme of nature.

Suppose there is placed before us a machine for raising great weights; be it the simplest of all, the wheel and axle. We are given to understand that this piece of mechanism has the property of multiplying the power of the hand. But a youth of subtile mind may say, I do not believe it possible so to *multiply* the power of the hand; and if the mechanician be a philosopher, he will rather applaud the spirit of doubt. If he condescend to explain, he will say, that the piles driven into

the ground, or the screws uniting the machinery to the beams, are the fixed points which resist in the working of the machine; that their resistance is a necessary condition, since it is thrown, together with the power of the hand, on the weight to be raised; and he will add that the multiplication of wheels does not alter the principle of action, which every one may see in the simple lever, to result from the resistance of the fulcrum or point, on which it rests.

Now grant that man's body is a machine, where are the points of resistance? are they not in the ground we stand upon? This leads us to inquire by what property we stand. Is it not by the weight of the body, or, in other words, by the Attraction of the earth? The terms attraction or gravitation lead at once to the philosophy of the question. We stand because the body has weight, and a resistance in proportion to the matter of the animal frame and the magnitude of the globe itself. We need not stop at present to observe the adjustment of the strength of the frame, the solidity of the bones, the elasticity of the joints, and the power of the muscles, to the weight of the whole. Our attention is directed to the relations which the frame has to the Earth we are placed upon.

Some Philosophers who have considered the matter curiously, have said, that if man were translated bodily to another Planet, and that planet were smaller than the earth, he would be too light, and he would walk like one wading in deep water: that on the contrary, if the planet were larger, the attraction of his body would make him feel as if his limbs were loaded with lead; nay, that the attraction might be so great as to destroy the fabric of the body, crushing bones and all.*

However idle these fancies may be, there is no doubt that the animal frame is formed with a due relation to the earth we inhabit; and that the strength of the materials of the animal body have as certainly a correspondence with the weight, as the wheels and levers of a machine, or the scaffolding which sustains them, have relation to the force and velocity of the machinery, or the load they are employed to raise.

The mechanism and organisation of animals have been often brought forward for a different purpose from that for which I

* The matter of Jupiter is as 330,600 to 1000 of our Earth. The diameter of Pallas is 80 miles; that of the Earth is 7911 miles.

use them. We find it said, that it is incomprehensible how an all-powerful Being should manifest his will by these means—that mechanical contrivance implies difficulties overcome; and how strange it is, they add, that the perceptions of the mind, which might have been produced by some direct means, or have arisen spontaneously, should be received through an instrument so fine and complex as the eye;—and which requires the creation of the element of light, to enter the organ and to cause vision.

For my own part, I think it most natural to contemplate the subject quite differently. We perhaps presume too much when we say that Light has been created for the purpose of Vision. We are hardly entitled to pass over its properties as a chemical agent, its influence on the gases, and, in all probability, on the atmosphere, its importance to vegetation, to the formation of the aromatic and volatile principles, and to fructification, its influence on the animal surface by invigorating the circulation, and imparting health. In relation to our present subject, it seems more rational to consider light second only to attraction for its importance in nature, and as a link connecting systems of infinite remoteness.

To have a conception of this, we must tutor our minds and acquire some measure of the velocity of light, and of the space which it fills. It is not sufficient to say that it moves 200,000 miles in a second; for we can comprehend no such degree of velocity. If we are further informed that the earth is distant from the sun 95,000,000 of miles, and that light traverses the space in 8 minutes and 1-8th, it is but another way of affirming the inconceivable rapidity of its transmission. Astronomers, whose powers of mind afford us the very highest estimate of human faculties, whose accuracy of calculation is hourly visible, have affirmed that light emanates from celestial bodies at such vast distance that thousands of years shall elapse during its progress to our earth—yet that, impelled by a force equal to its transmission through that space, it enters the eye and strikes upon the delicate nerve, with no other effect than to produce vision.*

Instead of supposing light created for the eye, and to give us the sense of vision, would it not be a more just manner of considering the subject to dwell with admiration on the fact, that

* The argument is not weakened on assuming the hypothesis that light results from the movement of an elastic ether.

this small organ, the eye, should be formed with relation to a system of such vast extent and grandeur; and, more especially, that the ideas arising in the mind through the influence of that light and this organ, should be constituted a part of one vast whole!

By such considerations we are led to contemplate the human body in its different relations. The magnitude of the earth determines the strength of our bones, and the power of our muscles; so must the depth of the atmosphere determine the condition of our fluids, and the resistance of our blood vessels; the common act of breathing, the transpiration from the surfaces, must bear relation to the weight, moisture, and temperature of the medium which surrounds us. A moment's reflection on these facts proves that our body is formed with a just correspondence to all these external influences: and not the frame of the body only, but also the vital endowments and the properties of the organ of sense. It were a perverseness to say that the outward senses, the organisation, and the vital properties, could arise from the influence of the surrounding elements, or out of matter spontaneously; they are created in accordance with the condition of the globe, and are systematic parts of a great whole.

These views lead to another consideration, that it is to external nature, and not of necessity to the mind, that the complexity of our structure belongs. Whilst man is an agent in a material world, and sensible to the influence of things external, complexity of structure is a necessary part of his constitution. But we do not perceive a relation between this complexity and the mind. From aught that we learn by this mode of study, the mind may be as distinct from the bodily organs as the exterior influences are which give them exercise.

Something, then, we observe to be common to our planet and to others, to our system and to other systems; matter, attraction, light; which nearly implies that the mechanical and chemical laws must be the same throughout. It is perhaps too much with an anonymous author to affirm, that an inhabitant of our world would find himself at home in any other; that he would be like a traveller, for a moment only perplexed by diversity of climate and strangeness of manners, but ready to confess, at last, that nature was everywhere and essentially the

same. However this may be, all I contend for is the necessity of certain relations being established between the planet and the frames of all which inhabit it; between the great mass and the physical properties of every part; that in the mechanical construction of animals, as in their endowments of life, they are created in relation to the whole, planned together and fashioned by one Mind.

A comparison made between the system of an animal body, and the condition of the earth's surface, is highly illustrative of design in both. In the animal, we see matter withdrawn from the influences which arrange things dead and inorganic; but this matter, thus appropriated to the animal, and newly endowed through the influence of life, continues to possess such qualities of inanimate matter as are necessary to constitute the living being a part of the system—an inhabitant of the earth. To what, then, does this argument lead? Is it not, that as the beautiful structure of the animal, and the perfection in the arrangement of its parts, demonstrate design—so design extends to the condition of the earth also; and over both there is a ruling Intelligence?

Men who have studied deeply, and who have become authorities in natural science, acquire a happy spirit of contentment and true philosophy, of which we have examples in Grew,* in Ray, and in Linnæus. The last, resting from his great labours in universal nature, and struck with the perfection and order evinced in the whole, breaks out, very naturally and eloquently, in admiration of the just relation of all things, as proving them to be the work of one Almighty Being. Then considering the great globe as a Museum,† furnished forth with the works of the Supreme Being, man, he adds, is placed in the midst of it, as alone capable of comprehending and valuing it. And if this be true, as certainly it is, what then becomes his duty? Moralists and divines, with Nature herself, testify that the purpose of so much beauty and perfection being made manifest to man, is that he may study and celebrate the works of God: and that if he fail in this, he will be wanting in those contem-

* A naturalist, who wrote on the anatomy of Plants; also, "*Cosmologia Sacra:* a Discourse on the Universe, as the creature and kingdom of God."

† These sentiments are best expressed in his Preface to the Catalogue of the Museum of Adolphus Frederick of Sweden.

plations and exercises by which the mind is to be raised to the knowledge of God. Those who say that the Scriptures ought to be the sole guides, forget that these are addressed to intelligent beings; and what can be more fitting to bestow that intelligence and capacity which is to receive eternal truths, than those studies which the great naturalist is enforcing, when he says, "If we have no faith in the things which are seen, how should we believe those which are not seen? The brute creatures, although furnished with external senses, resemble those animals which, wandering in the woods, are fattened with acorns, but never look upwards to the tree which affords them food; much less have they any idea of the Beneficent Author of the tree and its fruit." By such reflections was Linnæus led to conclude, that "whoever shall regard with contempt the economy of the Creator here, is as truly impious as the man who takes no thought of the future."

The passiveness which is natural in infancy, and the want of reflection as to the sources of enjoyment which is excusable in youth, become insensibility and ingratitude in riper years. In the early stages of life, before our minds have the full power of comprehension, the objects around us serve but to excite and exercise the outward senses. But in the maturity of reason, philosophy should present these things to us anew, with this difference, that the mind may contemplate them: that mind which is now strengthened by experience to comprehend them, and to entertain a grateful sense of them.

It is this sense of gratitude which distinguishes man. In brutes, *the attachment to offspring for a limited period* is as strong as in him, but it ceases with the necessity for it. In man, on the contrary, the affections continue, become the sources of all the endearing relations of life, and the very bonds by which society is connected.

If the child upon the parent's knee is unconsciously incurring a debt, and strong affections grow up so naturally that nothing is more universally condemned than filial ingratitude, we have but to change the object of affection, to find the natural source of religion itself. We must show that the care of the most tender parent is in nothing to be compared with those provisions for our enjoyment and safety, which it is not only beyond the ingenuity of man to supply to himself,

but which he can hardly comprehend, while he profits by them.

If man, of all living creatures, be alone capable of gratitude, and through this sense be capable also of religion, the transition is natural; since the gratitude due to parents is abundantly more owing to Him "who saw him in his blood, and said, Live."

For the continuance of life a thousand provisions are made. If the vital actions of a man's frame were directed by his will, they are necessarily so minute and complicated, that they would immediately fall into confusion. He cannot draw a breath, without the exercise of sensibilities as well ordered as those of the eye or ear. A tracery of nervous cords unites many organs in sympathy; and if any one filament of these were broken, pain and spasm and suffocation would ensue. The action of his heart, and the circulation of his blood, and all the vital functions, are governed through means and by laws which are not dependent on his will; and to which the powers of his mind are altogether inadequate. For had they been under the influence of his will, a doubt, a moment's pause of irresolution, a forgetfulness of a single action at its appointed time, would have terminated his existence.

Now, when man sees that his vital operations could not be directed by reason—that they are constant, and far too important to be exposed to all the changes incident to his mind, and that they are given up to the direction of other sources of motion than the will, he acquires a full sense of his dependence. If he be fretful and wayward, and subject to inordinate passion, we perceive the benevolent design in withdrawing the vital motions from the influence of such capricious sources of action, so that they may neither be disturbed like his moral actions, nor lost in a moment of despair.

Ray, in speaking of the first drawing of breath, delivers himself very naturally: "Here, methinks, appears a necessity of bringing in the agency of some superintendent intelligent Being, for what else should put the diaphragm and the muscles serving respiration in motion all of a sudden so soon as ever the fœtus is brought forth? Why could they not have rested as well as they did in the womb? What aileth them that they must needs bestir themselves to get in air to maintain the creature's

life? Why could they not patiently suffer it to die? You will say the spirits do at this time flow to the organs of respiration, the diaphragm, and other muscles which concur to that action and move them. But what raises the spirits which were quiescent, &c., I am not subtile enough to discover."

We cannot call this agency a new intelligence different from the mind, because, independently of consciousness, we can hardly so define it. But a sensibility is bestowed, which being roused (and it is excited by the state of the circulation,) governs these muscles of respiration, and ministers to life and safety, *independently of the will.*

When man thus perceives, that in respect to all these vital operations he is more helpless than the infant, and that his boasted reason can neither give them order nor protection, is not his insensibility to the Giver of these secret endowments worse than ingratitude? In a rational creature, ignorance of his condition becomes a species of ingratitude; it dulls his sense of benefits, and hardens him into a temper of mind with which it is impossible to reason, and from which no improvement can be expected.

Debased in some measure by a habit of inattention, and lost to all sense of the benevolence of the Creator, he is roused to reflection only by overwhelming calamities, which appear to him magnified and disproportioned; and hence arises a conception of the Author of his being more in terror than in love.

There is inconsistency and something of the child's propensities still in mankind. A piece of mechanism, as a watch, a barometer, or a dial, will fix attention—a man will make journeys to see an engine stamp a coin, or turn a block; yet the organs through which he has a thousand sources of enjoyment, and which are in themselves the most exquisite in design, and the most curious both in contrivance and mechanism, do not enter his thoughts; and if he admire a living action, that admiration will probably be more excited by what is uncommon and monstrous, than by what is natural and perfectly adjusted to its office—by the elephant's trunk, than by the human hand. This does not arise from unwillingness to contemplate the superiority or dignity of our own nature, or from incapacity of admiring the adaptation of parts. It is the effect of habit. The human hand is so beautifully formed, it has so fine a sensibility,

that sensibility governs its motions so correctly, every effort of the will is answered so instantly, as if the hand itself were the seat of that will; its actions are so powerful, so free, and yet so delicate, as if it possessed a quality of instinct in itself, that there is no thought of its complexity as an instrument, or of the relations which make it subservient to the mind; we use it as we draw our breath, unconsciously, and have lost all recollection of the feeble and ill-directed efforts of its first exercise, by which it has been perfected. Is it not the very perfection of the instrument which makes us insensible to its use? A vulgar admiration is excited by seeing the spider-monkey pick up a straw, or a piece of wood, with its tail; or the elephant searching the keeper's pocket with his trunk. Now, if we examined the peculiarity of the elephant's structure fully, that is to say, from its huge mass deduced the necessity for its form, and from the form the necessity for its trunk, it would lead us, through a train of very curious observations, to a more correct notion of that appendage, and therefore to a truer admiration of it; but I contrast this part with the human hand, merely to show how insensible we are to the perfections of our own frame, and to the advantages attained through such a form. We use the limbs without being conscious, or, at least, without any conception of the thousand parts which must conform to a single act. To excite attention, the motions of the human frame must either be performed in a strange and unexpected mode, that will raise the wonder of the ignorant and vulgar; or we must rouse ourselves, by an effort of the cultivated mind, to observe things and actions, of which the sense has been lost by long familiarity.

In the following pages, I shall treat the subject comparatively; and exhibit a view of the bones of the arm, descending from the human Hand to the Fin of the fish. I shall in the next place review the actions of the Muscles of the arm and hand. Then proceeding to the vital properties, I shall advance to the subject of Sensibility, leading to that of Touch; afterwards, I shall show the necessity of combining the Muscular Action with the exercise of the senses, and especially with that of touch, to constitute the hand, what it has been called, the geometrical sense. I shall describe the organ of touch, the cuticle and skin, and arrange the nerves of the hand according to their functions. I shall then inquire into the correspondence between the capa-

cities or endowments of the mind, and the external organs, and more especially the properties of the hand. And I shall conclude by showing that animals have been created with a reference to the globe they inhabit; that all their endowments and various organisation bear a relation to their state of existence, and to the elements around them; that there is a plan universal, extending through all animated nature, and which has prevailed in the earliest condition of the world; and finally, that on the most minute, or the most comprehensive, study of those subjects, we everywhere behold Prospective Design.

CHAPTER II.

DEFINITION OF THE HAND.

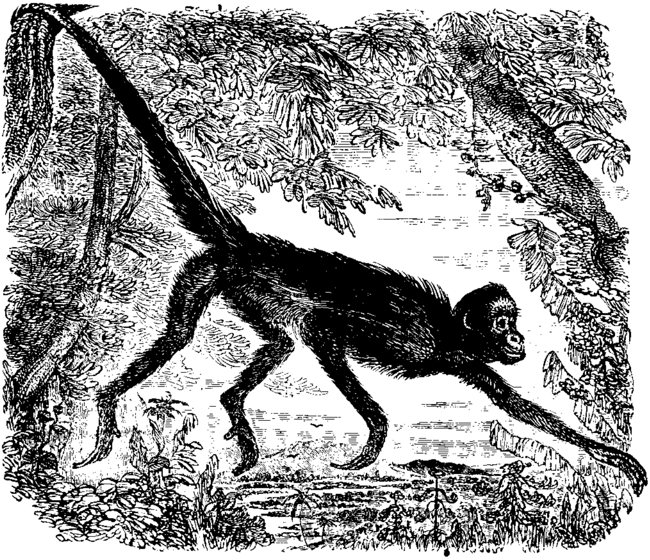
THE ARMS AND HAND, VARIOUSLY MODIFIED, ADAPTED TO AN EXTENSIVE SYSTEM OF ANIMALS.

WE ought to define the Hand as belonging exclusively to Man —corresponding in its sensibility and motion to the endowments of his Mind, and especially to that ingenuity which, through means of it, converts the being who is the weakest in natural defence, to be the ruler over animate and inanimate nature.

If we describe the hand, including the arm, as an extremity in which the thumb and fingers are opposed to each other, so as to form an instrument of prehension, we embrace in the definition the extremities of the quadrumana or monkeys. Now, as these animals possess four such hands, it implies that we include the posterior as well as the anterior extremities. But the anterior extremity of the monkey is as much a foot as the posterior extremity is a hand: both are calculated for their mode of progression, climbing, and leaping from the branches of trees; just as the tail in some species is converted to the same purpose, and is as useful an instrument of suspension as any of the four extremities.*

* The following is a sketch of the Coaita, or Spider Monkey, so called from the extraordinary length of its extremities, and from its motions. The tail answers all the purposes of a hand, and the animal throws itself about from branch to branch, sometimes swinging by the foot, sometimes by the fore extremity, but oftener, and with a greater reach, by the tail. The prehensile part of the tail is covered with skin only, forming an organ of touch as discriminating as the proper extremities. The Caraya, or Black Howling Monkey of Cumana, when shot, is found suspended by its tail round a branch. Naturalists have been so struck with the property of the tail of the Ateles, that they have com-

The armed extremities of a variety of animals give them great advantages. But if man possessed similar provisions, he would



forfeit his sovereignty over all. As Galen, long since, observed, "did man possess the natural armour of the brutes, he would no longer work as an artificer, nor protect himself with a breast-plate, nor fashion a sword or spear, nor invent a bridle to mount the horse and hunt the lion. Neither could he follow the arts of peace, construct the pipe and lyre, erect houses, place altars, inscribe laws, and through letters and the ingenuity of the hand, hold communion with the wisdom of antiquity, at one time to converse with Plato, at another with Aristotle, or Hippocrates."

But the hand is not a distinct instrument; nor is it properly

pared it to the proboscis of the Elephant. They have assured us that they fish with their tail.

The most interesting use of the tail is seen in the Opossum. The young of that animal mount upon her back, and entwine their tails around their mother's tail, by which they sit secure, while she escapes from her enemies.

a superadded part. The whole frame must conform to the hand, and act with reference to it. Our purpose will not be answered by examining it alone; we must extend our views to all those parts of the body which are in strict connexion with the hand. For example, from the shoulder to the finger ends, such a relation is established amongst the whole chain of bones, that it is essential to embrace the whole extremity in the inquiry. And in order to comprehend fully the fine arrangement of the parts necessary to the motions of the fingers, we must compare the structure of the human body with that of other animals.

Were we to limit our examination to the bones of the arm and hand in man alone, no doubt we should soon discover the provisions in them for easy, varied, and powerful action; and conclude that nothing could be more perfectly suited to their purposes. But we must extend our views to comprehend a great deal more—a larger design.

By a Skeleton, is understood the system of bones, constructed within, which gives firmness and characteristic form to the animal, and receives the action of the exterior muscles. This osseous system belongs, however, to one part only of the animal kingdom; that higher division — the Animalia Vertebrata* —which includes the chain of beings from man down to fishes.

To life, the most essential function is Respiration; and on the mode in which that is performed, or in which the decarbonisation of the blood is effected by its exposure to the atmosphere, depends a remarkable change, in the animal kingdom, of the whole framework of the body. As man, the mammalia, birds, reptiles, and fishes have the mechanism of respiration much in common, so, through them all, a resemblance can be traced in the structure of their bones, in the action of their muscles, and in the arrangement of their nerves. They all possess the Vertebral Column or Spine; and the existence of that column not only implies an internal skeleton, but that particular framework of ribs which is suited to move the lungs in breathing.

But the ribs do not move of themselves; they must have

* See the first of the ADDITIONAL ILLUSTRATIONS. *Vertebra* is the name given to one of the bones of the spine, or backbone.

appropriate muscles. These muscles must have their appropriate nerves: and for supplying these nerves, there must be a Spinal Marrow. The spinal canal formed within the vertebral column, is to the spinal marrow as necessary as the skull to the Brain. So that we come round to understand the necessity of a vertebra to the formation of a spinal marrow; and the reader may comprehend how much enters into the conception of the anatomist or naturalist, when the term, a vertebrated animal, is used, viz.,—an internal skeleton, a particular arrangement of respiratory organs, and a conformity in the Nervous System.

In making a review of the bones of the upper extremity, I shall limit myself to this superior division of Vertebrated animals.

If in commencing this subject, and indulging in the admiration which naturally arises out of it, I were to point, in the upper extremity, to the strength and freedom of motion at the ball and socket joint of the shoulder,—to the firmness of the articulation at the elbow, with its admirable combination of mobility suited to the co-operation of the hands,—to the latitude of motion at the wrist, with its strength,—and to the fineness of the movements of the hand itself, divided among the joints of twenty-nine distinct bones—some, objecting with a show of reason, might say—The bones and forms of joints you are thus admiring, so far from being peculiarly suited to the hand of man, may be found in any other vertebrated animal! But that remark would not abate our admiration; it would only remind us that we erred in looking at a part only, instead of embracing a comprehensive system; where by slight, hardly-perceptible changes and gradations in the forms, the analogous bones were adjusted to every condition of animal existence.

Nothing can be adapted more correctly and appropriately for their object, than the bones by which the motions of the upper extremity are performed. We enjoy the power of bending and coiling the arm, extensively and freely—and of reaching the fingers to every part. Yet these bones, so truly admirable in man, are recognised in the fin of the whale, in the paddle of the turtle, and in the wing of the bird; we see the corresponding bones, perfectly suited to their purpose, in the paw of the lion, or the bear; and equally fitted for motion in the hoof of the

horse, or in the foot of the camel; or adjusted for climbing or digging, in the long-clawed feet of the sloth or bear.

It is obvious, then, that we should be unduly limiting our subject, if we did not consider the human hand in its relation to the corresponding organs of other animals: as exhibiting the bones and muscles, which in different animals are suited to particular purposes, so combined in the Hand as to perform, consistently with powerful exertion, actions the most minute and complicated. The wonder still is, that whether we examine the system in man, or in any of the inferior species of animals, nothing can be more curiously adjusted or appropriated; and whatever instance occupied our thoughts for the time, we should be inclined to say, that to that particular object it had been framed.

The view which the subject opens, is unbounded. It is upon a knowledge of the system of which we are speaking, that the curious synthesis, by which we ascertain the nature, condition, and habits of an extinct animal, from the examination of its fossil remains, is grounded. To make the proper use of that department, we must understand what a fossil bone is.

A bone consists of many parts; but for our present purpose it is necessary to observe only that the hard substance, which we familiarly recognise as bone, is formed of an earthy material, the phosphate of lime, everywhere penetrated by membranes and vessels, as delicate as those in any other structures of the body. Fossil bones are those found imbedded in the earth, and they may be in different conditions. They may either retain their natural structure, or may have become petrified; that is to say, the animal matter may have been decomposed and dissipated, with the phosphoric acid of the phosphate of lime; and then, silicious earth, or lime in composition with iron, or iron pyrites, may by solution and infiltration fill the interstices of the original matter of the bone. Thus bone will be converted into stone, and be as permanent as the rock which contains it; it will retain the form though not the internal structure of its original.

Now that form, in consequence of the perfect system which we have hinted at, becomes the proof of revolutions in the face of the earth the most extraordinary. By reasoning on such fossil bones, the mind of the inquirer is conducted back, not

merely to the contemplation of the structure of the animal of which they are the remains, but by inference from the animal organisation, to that of the changes in the globe itself.

In the highest mountains of the old and new world, remains of marine animals are found; and on turning up the surface of our fields, or in the beds of rivers, huge bones are discovered not in the loose soil only, but under the solid limestone rock now the bones thus exposed become naturally a subject of intense interest, and bear unexpectedly on the inquiry in which we are engaged. Among other important conclusions, they enforce this—that not only does a scheme or system of animal structure pervade all classes of animals which now inhabit the earth, but that the principle of the same great plan of creation was in operation, and governed the formation of those animals which existed previous to the revolutions that the earth has undergone: that the excellence of form now visible in the human skeleton, was in the scheme of animal existence, long previous to the formation of man, before the surface of the earth was prepared for him, or suited to his constitution, structure, or capacities.

A skeleton is dug up, which has lain under many fathoms of rock, *being the bones of an animal* which *lived antecedent* to that formation of rock, and at a time when the earth's surface must have been very different from what it now is. These remains prove that the animal must have been formed of the same constituent elements as those of the present day; that it had analogous organs—received new matter by digestion, and was nourished by means of a circulating fluid—possessed feeling through a nervous system, and was moved by the action of muscles. With regard also to other animals of the same period, we may infer that, as in those now alive, the organs of digestion, circulation, and respiration, would be modified by circumstances, in accordance with their habits and modes of living; and that such changes, being but variations in the system by which new matter is assimilated to the animal body, would always, however remarkable they were, bear a relation to the original type, as parts of one great design.

In examining these bones of the ancient world, so regularly are they constituted on the same principle evinced in animals which now inhabit the earth, that by observing their shape, and

the processes* by which their muscles were attached, the anatomist can reduce the animals to which they belonged, to their orders, genera, and species, with as much precision as if the recent bodies had been submitted to his eye. Not only can we distinguish whether their feet were adapted to the solid ground, or to the oozy bed of rivers,—to speed, or to grasping and tearing; but judging, by these indications, of the habits of the animals, we acquire a knowledge of the condition of the earth during their period of existence: ascertain that at one time it was suited to the scaly tribe of the lacertæ, with languid motion; at another, to animals of higher organisation, with more varied and lively habits; and finally we learn, that at any period previous to man's creation, the surface of the earth would have been unsuitable to him.

We ought not to touch on this subject without one observation more. When the peasant, on turning up the great bones of some unknown animal, suspends his work and thinks he has discovered the limbs of a giant, he is more to be excused than the learned and ingenious, who seek from these natural appearances to illustrate the Scriptures. True religion is adapted to the sound capacities of all men—to that condition of mind which the individual experience of the good and evil of the world, sooner or later, brings with it: it is suited to man in every stage of the progress of society—to his weakness and to his strength; from which it becomes the real dispenser of equal rights. Had our religion been framed with a relation to science, it could not have been adapted to every man; least of all had it been related to that branch of natural knowledge which is called Geology—a science so obviously in its infancy, that but for its alliance with anatomy, it would have continued to present a scene only of confusion for ignorant wonderment.

It may then be asked, why do we cultivate those scientific subjects to which we apply the term Natural Religion? Because they agreeably enlarge our comprehension, and, while they repress a too selfish enthusiasm, exalt the imagination. We all of ourselves proceed a certain length in the examination of natural phenomena; and the convictions arising from the

* Processes are the projecting points of bone by which the tendons of the muscles are attached. To the anatomist, therefore, processes are indications of the condition of the muscles.

survey are wrought into the opinions of every one. Yet when benevolent design is disclosed by new facts, or by things that are familiar being presented in a new light, we experience a fresh and cheerful influence. We are sensible of a renewed impulse; a gratification which interferes with no duty.

This opportunity may be taken to correct a notion which we have seen expressed, that certain imperfections are discoverable in the structure of some animals. Such an idea must have sprung from comparing these animals with ourselves, our structure, and sensibilities—instead of looking on them with reference to their peculiar conditions.

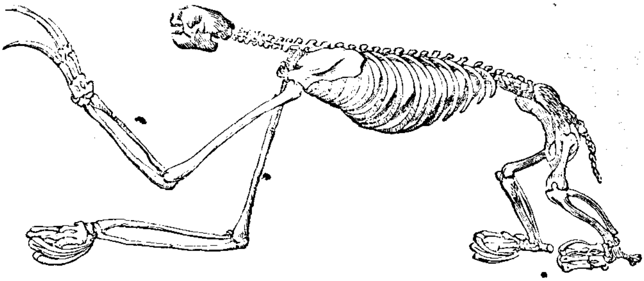
For example, the eloquent Buffon, when comparing the present races of animals with the fossil remains of individuals of the same family now extinct, expresses some singular opinions; which, although with reserve, have been adopted even by Cuvier. Buffon speaks confidently of the unsuitableness of particular organs of animals, and of the derangement of their instincts. But it is from comparing them and their mode of life with human society, a state where individuals are subject to misery and want. He surely sympathises too closely with the bird of prey, when he characterises its watchfulness as a true picture of wretchedness, anxiety, and indigence. If a bird refuse to be domesticated and crammed with meat, it is hardly fair to accuse it of gloom and apathy, the simple fact being that such treatment is contrary to its natural habits and instincts. The animals which principally excite his commiseration, are of the tardigrade family, the sloths: in the Ai,* for example, the defect of organisation is, he supposes, the greatest; and the Unau,† he thinks, is only a little less miserably provided for existence.

In like manner, modern travellers express pity for these slow-paced animals. Whilst other quadrupeds, they say, range in boundless wilds, the sloth hangs suspended by his strong arms, —a poor, ill-formed creature, deficient as well as deformed, his hind-legs too short, and his hair like withered grass; his looks, motions, and cries, conspire to excite pity; and, as if this were not enough, they say that his moaning causes the tiger to relent

* Bradypus tridactylus :—bradypus (*slow-footed*), tridactylus (*three-toed*), of the order EDENTATA (*wanting incisor teeth*).

† Bradypus didactylus (*two-toed.*)

and turn away. But that is not a true picture: the sloth cannot walk like many other quadrupeds, but he stretches out his



Skeleton of the Sloth.

arms, and if he can hook on his claws to the inequalities of the ground, he drags himself along. This condition it is which gives occasion to such an expression as "the bungled and faulty composition of the sloth." But if with his claws he can reach the branch or the rough bark of a tree, then will his progress be rapid; he will climb hand over head along the branches till they touch, thus getting from bough to bough, and tree to tree; in the storm he is most alive; it is when the wind blows, and the trees stoop, and the branches wave and meet, that he is upon the march.*

Accordingly, the compassion expressed by these philosophers for animals which they consider imperfectly organised, is uncalled for.† As well might they pity the larva of the summer fly, which creeps at the bottom of a pool, because it cannot yet rise upon the wing. As the insect, until its metamorphosis is perfect and its wings developed, has no impulse to fly, so there is no reason to suppose that a disposition or instinct is given to animals without a corresponding provision for motion. On the ground, the sloth may move tardily; his long arms and preposterous claws may then be an incumbrance; but in his natural place, among the branches of trees, they are of advantage in

* Waterton.

† The subject is pursued at the end of the following chapter.

obtaining his food, and in giving him shelter and safety from his enemies.

It is not by our own sensations that we must estimate the movements of animals. In catching a fly the motion of the bill of the swallow or of the fly-catcher is so rapid that we do not see it, but only hear the snap. On the contrary, how very different are the means employed by the chameleon for obtaining his food; he lies more still than the dead leaf, his skin like the bark of the tree, and taking the hue of the surrounding objects: whilst other animals evince excitement conforming to their rapid motions, his shrivelled face hardly indicates life: his eyelids are scarcely parted; he protrudes his tongue towards the insect, with a motion so imperceptible, that it is touched and caught more certainly than by the most lively action. Thus, various creatures, living upon insects, reach their prey by different means and instincts; some by rapidity of motion, which gives no time for escape, others by a languid and slow movement that excites no alarm.

The loris, a tardigrade animal, might be pitied too for the slowness of its movements, if these were not necessary to its very existence. It steals on its prey by night, and extends its

arm towards the bird on the branch, or the great moth, with a motion so imperceptibly slow as to make sure of its object.*

* It may be well to notice some other characters that belong to animals, inhabitants of the tropical regions, which prowl by night. The various creatures that enliven the woods in the day-time, in these

Just so the Indian, perfectly naked, his hair cut short, and his skin oiled, creeps under the canvas of the tent, and moving like a ghost, stretches out his hand with a motion so gentle as to displace nothing, not even disturbing those who are awake and watching. Against such thieves, we are told, it is hardly possible to guard. And thus, the necessities or vicious desires of man subjugate him, and make him acquire by practice the wiliness implanted in brutes as instinct. Or we may say that, endowed with reason, man is brought to imitate the irrational creatures, and so to vindicate the necessity for their particular instincts; of which every class affords examples.

In insects, the illustrations of such actions are as striking as in the loris, or the chameleon. Evelyn describes a spider (*Aranea scenica*) as exhibiting remarkable cunning in catching a fly. "Did the fly," he says, "happen not to be within a leap, the spider would move towards it so softly, that its motion seemed not more perceptible than that of the shadow of the gnomon of a dial,"* and then it would suddenly pounce upon its prey.

I would only remark further, that we are not to account this slowness a defect, but rather an appropriation of muscular power: since in some animals, the same muscles which at one time produce a motion so slow as to be hardly perceptible, can at another act with the velocity of a spring.

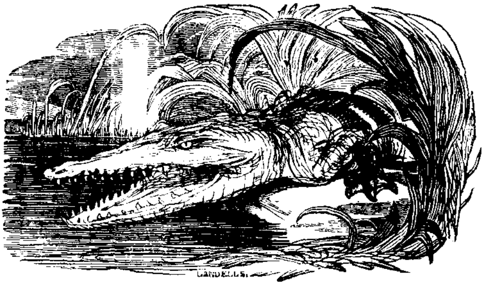
Now Buffon, speaking of the extinct species of the tardigrade family, has represented them as monsters, by defect of organisation: as attempts of nature, wherein she has failed to perfect

warm climates, have fine skins, and smooth hair; but those that seek their prey at night have a thick coat like animals of the arctic regions. What is this but to be clothed as the sentinel whose watch is in the night? They have eyes, too, which, from their peculiar structure, are called nocturnal, being formed to admit a large pencil of rays of light, and having the globe full and prominent, and the iris contractile, to open the pupil to the greatest extent. We have seen how their motions and instincts correspond with their nocturnal habits.

* The passage continues—"If the intended prey moved, the spider would keep pace with it exactly as if they were actuated by one spirit, moving backwards, forwards, or on each side without turning. When the fly took wing and pitched itself behind the huntress, she turned round with the swiftness of thought, and always kept her head towards it, though to all appearance as immoveable as one of the nails driven into the wood on which was her station; till at last, being arrived within due distance, swift as lightning she made the fatal leap, and secured her prey."—Evelyn, as quoted by Kirby and Spence.

her plan: implying that she has produced animals which must have lived miserably, and which she has effaced from the list of living beings as failures. The Baron Cuvier does not express himself more favourably, when he says of the existing species, that they present so little resemblance to the organisation of animals generally, and their structure is so much in contrast with other creatures, that he could believe they were the remnants of an order unsuited to the present system of nature; and we must seek for their congeners in the interior of the earth, in the ruins of the ancient world.

But the animals of the Antediluvian world were not monsters; there was no lusus or extravagance. Hideous as they appear, and like the phantoms of a dream, they were adapted to the condition of the earth when they existed. I could have wished that our naturalists had applied to the inhabitants of that early condition of the globe, names less scholastic; we have the plesiosaurus, and plesiosaurus dolichodeiros, and ichthyosaurus, megalosaurus, and hylæosaurus, and iguanodon, pterodactyles, with long and short beaks, tortoises, and crocodiles; these are found among reeds and grasses of gigantic proportions, algæ



and fuci; and a great variety of mollusca, of inordinate bulk compared with those of the present day, as ammonites and nautili, are discovered in the same spots. Everything declares that these animals inhabited shallow seas, and estuaries, or great inland lakes: that the surface of the earth, at these parts, did not rise up in peaks and mountains, or perpendicular rocks bound in the seas; but that it was flat, slimy, and covered with a loaded and foggy atmosphere. Looking to the class of ani-

mals, as we have enumerated them, such a condition of the earth would correspond with them: they were scaly; they swam in water, or crept upon the margins; they were not exposed to animals possessing greater rapidity of motion, nor were there birds of prey to stoop upon them; there was, in short, a balance of the power of destruction and of self-preservation, the same as we see now obtaining in higher animals since created, with infinitely-varied instincts and means for defence or attack. There is, indeed, every reason to believe that at that period, the classes mammalia and birds* were not created. And it seems obvious that if man had been placed upon the earth, when it was in that condition, he must have had around him a state of things neither suited to his constitution nor calculated to call forth his capacities.

It is hardly possible to watch the night and view the break of day in a fine country, without being sensible that our pleasantest perceptions refer to the scenery of nature; and that we have feelings in sympathy with every successive change, from the first streak of light until the whole landscape is displayed in valleys, woods, and sparkling waters. The changes on the scene are not more rapid than the transitions of the feelings which attend them. Now, all these sources of enjoyment, the clear atmosphere and the refreshing breezes, are as certainly the result of the several changes which the Earth's surface has undergone in the different epochs of its formation, as the displaced strata within its crust are demonstrative of those changes. We have every reason to conclude that these revolutions, whether they have been slowly and progressively accomplished, or by sudden, vast, and successive convulsions, were necessary to prepare the earth for that condition which should correspond with the faculties to be given to Man, and be suited to the full exercise of his reason, as well as to his enjoyment.

If a man contemplate the common objects around him—if he observe the connexion between the qualities of things external and the exercise of his senses, between the senses so excited and the condition of his mind, he will perceive that he is in the

* In the secondary strata, of the period sometimes called "the age of Reptiles," fossil foot-prints, supposed to be the impressions on mud of the feet of Birds of gigantic stature, have been recently found. —(S.)

centre of a magnificent system, prepared for his reception by a succession of revolutions which have affected the whole globe; and that the strictest relation is established between his intellectual capacities and the material world.

In the succeeding chapter, we shall take a comparative view of the anatomy of the arm; and as we trace the same parts through different genera and species of animals, some extraordinary changes in their forms will be presented. But before proceeding to make that survey, we are naturally called upon to notice certain opinions which prevail on the subject.

However interesting the recent inquiries of geologists may be, they encourage a certain licence of fancy. During the remote periods, dark in every sense, when mounds of stratified rock were forming under interminable seas, what were the animated beings suited to live in the then condition of the elements, must be matter of conjecture. Materialists have long entertained the question, did the first egg proceed from a bird, or the bird from the egg?—But the hundred and ninety-nine theories on the sources of life and organisation, and on the origin of animals, whether by ancient or modern philosophers, are all fanciful, wild, and unphilosophical, having no ground to rest upon!—Nothing is satisfactory until it is declared and believed, that it has been the will of an Omnipotent Being to create—to form the earth and to give life; and that it was He who appointed the changes to be wrought on the material, and gave the animating principle to produce organisation in correspondence with these changes.

We have already hinted that, in the stratified rocks composing the crust of the earth, geologists have discovered proofs of a regular succession of formations; and that animals of very different structure have been imbedded, and are preserved in these successive layers. In the earlier-formed strata, animals are found which are low, as we choose to express it, in the chain of existence; in higher strata, oviparous reptiles of great bulk, and more complex structure, are discovered; above the strata containing these oviparous reptiles, there are found mammalia; and in the more superficial and recent strata, are the bones of the mastodon, megatherium, rhinoceros, and elephant, &c. We must add, that geologists agree that Man has been created last of all.

Upon these facts, a theory is raised, that there has been a

succession of animals gradually increasing in the perfection of their structure: that the first impulse of nature was not sufficient to the production of the highest and most perfect, and that it was only in her mature efforts that mammalia were produced.

But we are led to this reflection: that the very formation of a living animal, the bestowing Life on a corporeal frame, however simple the structure, is of itself an act of Creative Power so inconceivably great, that we cannot regard any change in the organisation, such as providing bones and muscles, or producing new organs of sense, as evincing a higher effort of that Power. In exploring, therefore, the varieties of animated nature, at those distinct epochs, we have a better guide, when we acknowledge the manifest Design with which all has been accomplished; and the adaptation of the animals, their size, their economy, their organs, and instruments, to their condition.

Whether we make the most superficial or most profound examination of animals in their natural state, we shall find that the varieties are so balanced as to insure the existence of all. This, we think, goes far to explain why the remains of certain *animals are found in strata which indicate a peculiar condition* of the earth's surface; and why particular animals only are found grouped together. For, as we may express it, if there had been an error in the grouping, there must have been a destruction of the whole; because the balance necessary to their existence must have been destroyed.

We know very well that so minute a thing as a fly will produce millions of the same kind, which, if not checked, will ere long darken the air and render whole regions desolate; so that if the breeze does not carry them in due time into the desert or into the ocean, the ravages committed by them will be most fearful. As in the present day every creature has its natural enemy, or is checked in production, sometimes by a limited supply of food, sometimes by disease, or by the influence of seasons, and as in the whole a balance is preserved, so we may reasonably apply the same principle to explain the condition of things existing in the earlier stages of the world's progress. Certainly, by what we have as yet discovered in the grouping of animals, in the different stratifications or deposits of the earth, this view is borne out.

If the naturalist or geologist, exploring the rocks of secondary formation, should find inclosed within them animals of the class mollusca, it would agree with his preconceived notions, that animals of their simple structure alone existed during the subsidence of the material of which the rock consists. But if the spine of a fish, or a jawbone, or a tooth, were discovered, he would be much disturbed; because here was the indication of an animal having been at that time formed on a different type,—on that plan which belongs to animals of a superior class. Had he, on the contrary, supposed that animals were created with a relation to those circumstances to which we have just alluded, the discovery of such remains would only imply that certain animals, which had hitherto increased undisturbed, had arrived at a period when their numbers were to be limited; or that the condition of the elements, and the abundance of food, were now suited to the existence of a species of the vertebrata.

*The principle, then, in the application of which we shall be borne out, is, that there is an adaptation, an established and universal relation between the instincts, organisation, and instruments of animals, on the one hand, and the elements in which they are to live, the position which they are to hold, and their means of obtaining food, on the other;—and this holds good with respect to the animals which have existed, as well as those which now exist.**

In discussing the subject of the progressive improvement of organised beings, it is affirmed that man, the last created of all, is not superior in organisation to the others; and that if deprived of intellectual power, he is inferior to the brutes. I am not arguing to support the theory of the gradual development and improvement of animals; but, however indifferent to the tendency of the argument, I must not admit the statement. Man is superior in organisation to the brutes—superior in strength—in that constitutional property which enables him to fulfil his destinies, by extending his race in every climate, and living on every variety of nutriment. On the other hand, gather together the most powerful brutes, from the arctic circle or torrid zone, to some central point—so ill suited is their constitution to the change, that diseases will be generated, and they will be

* These questions have given rise to controversy among eminent geologists. See Sir Charles Lyell's Anniversary Address, 1851.—(S.)

destroyed. With respect to the superiority of man being in his mind, and not merely in the provisions of his body, it is no doubt true;—but as we proceed, we shall find how the Hand supplies all instruments, and by its correspondence with the intellect, gives him universal dominion. It presents the last and best proof in the order of creation, of that principle of adaptation which evinces design.

Another opinion requires to be noticed. It is alleged that the variety of animals existing in the world is not a proof of design, or of there being a relation between the formation of their organs and the necessity for their exercise; but it is supposed that the circumstances in which the animals have been placed are the cause of the variety. It is pretended, that, in the long progress of time, the influence of these circumstances has produced a complication of structure out of an animal which was at first simple. We shall reserve the discussion of this theory until we have the data before us; which alone, without much argument, will suffice, we think, to overthrow it.

I may notice shortly another idea entertained by some naturalists, who are pleased to reduce these differences in the structure of animals, to general laws. It is affirmed that in the centre of the animal body, no disposition to change is manifested; whilst in the extremities, on the contrary, surprising variations of form are exhibited. If this be a law, there is no more to be said about it; the inquiry is terminated. But I contend that the term is quite inapplicable, and worse than useless, as tending to check inquiry. Why is the variation in the form most common in the extremities, whilst towards the centre of the skeleton there is comparative permanence? I conceive the rationale to be this: that the central parts, by which in fact we mean the skull, spine, and ribs, are in their offices permanent; whilst the extremities are adapted to every exterior circumstance. In all animals, the office of the cranial part of the skull is to protect the brain, that of the spine to contain the spinal marrow, and that of the ribs to perform respiration; why should we expect these parts to vary in shape, while their offices remain the same? But the shoulder, on the contrary, must vary in form, as it does in motion, in different animals; so must the shape of the bones and of the joints more distant from the centre be adapted to their various actions;

and the carpus, tarsus, and phalanges,* must change more than all the rest, to accommodate the extremities to their diversified offices. Is it not more pleasing to see the reason of this most surprising adjustment, than merely to say it is a law? †

There is yet another opinion, which after perusing the following chapter, will suggest itself to those who have read the more modern works on Natural History. It is supposed that the same elementary parts belong to all animals; and that it is to the transposition of these elementary parts that the varieties in their structure are attributable. I find it utterly impossible to follow up that theory to the extent which its abettors would persuade us to be practicable. I object to it as a means of engaging us in very trifling pursuits—and of diverting the mind from the truth; from that conclusion, indeed, to which I may avow it to be my intention to carry the reader. But this discussion also must follow the examples; and we shall resume it in a latter part of the volume.

* Carpus, the wrist; tarsus, the ankle or instep; phalanges, the rows of bones forming the fingers or toes.

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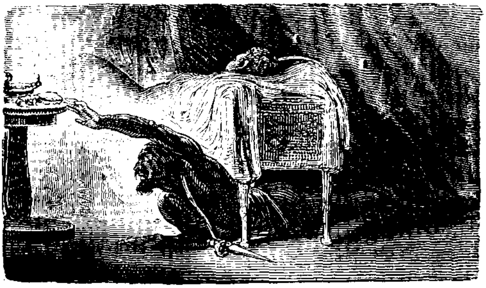

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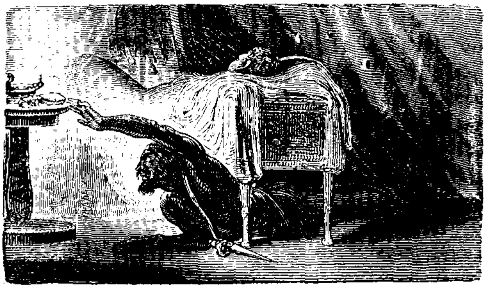


CHAPTER III.

THE COMPARATIVE ANATOMY OF THE HAND.

In this inquiry, we have before us what in the strictest sense of the word is a System. Of the extensive division of the animal kingdom which we are about to review, viz., the vertebrated animals, all the individuals possess a cranium for the protection of the brain,—a heart, implying a peculiar circulation,—and five distinguishable organs of sense; but the grand peculiarity, whence the term vertebrated is derived, is to be found in the Spine—that chain of bones which connects the head and body, and, like a keel, serves as the foundation of the ribs, or as the basis of the fabric through which respiration is performed.

We are to confine ourselves, as we have said, to a portion only of this combined structure; to examine separately the Anterior Extremity, and to observe the adaptation of its parts, through the whole range of the vertebrated animals. We shall view it as it exists in Man, and in the higher division of animals which give suck, the mammalia; and in those which propagate by eggs, the oviparous animals, birds, reptiles, and fishes. In so doing, we shall find the bones composing it identified by certain common features, and yet in all the series, from the arm to the fin, adjusted to various purposes. We shall recognise the same bones formed, in the mole, into a powerful apparatus for digging, by which the animal soon covers itself, and burrows its way under ground; in the wing of the eagle we shall count every

bone, and find that although adapted to a new element, they are as powerful to rise in the air, as the fin of the salmon is to strike through the water; the solid hoof of the horse, the cleft foot of the ruminant, the paw with retractile claws of the feline tribe, and that with long folding nails of the sloth, are among the many changes in the adjustment of the same chain of bones, which ministers in man to the compound motions of the Hand.

Were it my purpose to teach the elements of this subject, I should commence by examining, in the lowest vertebrated animals, the earliest traces of the bones of the anterior extremity, with the gradually-increasing resemblance to the human arm, as we ascended in the scale; and I should then point out the greater variety of uses served by them in the higher animals. But since my present object is illustration only, I shall begin with the human arm; and dividing it into the Shoulder, Arm, and Hand, treat each subdivision with a reference to its structure in inferior animals.

In viewing the human figure, or human skeleton, in connexion with our present subject, we cannot fail to remark the strength and solidity which belong to the lower extremities, in contrast with those of the superior. Not only are the lower limbs proportionably longer and larger in man than in any other animal, but the haunch-bones (pelvis) are wider. The distances of the large processes on the upper ends of the thigh-bones (the trochanters), from the sockets of the hips, are also greater than in any of the vertebrata. Altogether, the strength of the bones of the lower extremities, the size and prominence of their processes, the great mass of the muscles of the loins and hips, distinguish man from every other animal; they secure to him the upright posture, and give him the perfect freedom of the arms, for purposes of ingenuity and art.

At the head of this chapter is a sketch of the Chimpanzee,*

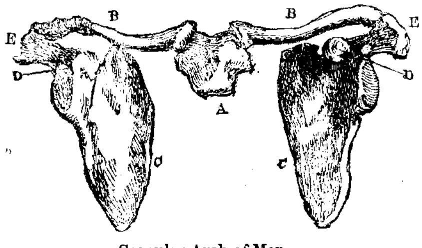
* *Simia troglodytes*, from the coast of Guinea, more human in its form, and more easily domesticated, than the ouran-outang. We would do well to consider the abode of these creatures in a state of nature—that they reside in vast forests, extending in impenetrable shade below, whilst above and exposed to the light, there is a scene of verdure and beauty. Such is the home of the monkeys and lemurs, that possess extremities like hands. In many of them the hinder extremity has a more perfect resemblance to a hand than the anterior; in the Cheiropaita (p. 13), we see the great toe assuming the characters of a thumb, whilst in the fore-paw the thumb is not distinguishable, but is hid in the skin. In short, these paws are not approximations to the hand, corresponding with a higher ingenuity, but are adaptations of the feet to the branches on which the animals climb and walk.

an ape which stands high in the order of quadrumana. Yet we cannot mistake his capacities; that the lower extremities and pelvis, or hips, were never intended to give him the erect posture, or only for a moment; but for swinging, or for a vigorous pull, who can deny the power in these long and sinewy arms?

The full, prominent shoulders, and consequent squareness of the trunk, are equally distinctive of man with the strength of his loins; they indicate free motion of the arm and hand.

The bones of the shoulder, which form the centre of motion of the upper extremity, and afford origins of attachment to the muscles of the arm, are simple in structure as they appear in man, or in any single animal; but if viewed in reference to their analogies in the different classes of the Vertebrata, they present remarkable varieties in shape, and assume an extraordinary degree of intricacy. In all their modifications of form, however, and notwithstanding the strange variations in the neighbouring parts, they retain their proper offices. In man, these bones lie supported on the ribs, and are directly connected with the great apparatus of respiration; but in certain animals, as in the frog, we shall see the ribs, as it were, withdrawn, and the bones of the shoulder curiously and mechanically adapted to perform their office, of giving a firm foundation to the extremity, without the support of the thorax. We shall not, however, anticipate the difficulties of the subject; but look first upon what is more familiar and easy, the shoulder in man, as compared with some of its varieties in the mammalia.

OF THE CLAVICLE.*



Scapular Arch of Man.

The clavicle, or collar-bone (B), runs across from the breast-bone (A) to the tip of the shoulder (E). The square form of the chest, and the free exercise of the hand, are very much owing to this

* A, Triangular portion of the Sternum, or breast-bone. B, B, Clavicle, or collar-bone. C, C, Scapula, or shoulder-blade. D, Coracoid process of the Scapula. E, Acromion process of the Scapula, forming the tip of the shoulder.

bone. It keeps the shoulders apart from the chest, and throws the action of the muscles proceeding from the ribs, upon the *arm-bone; which would otherwise* be drawn inwards, and contract the upper part of the trunk.

If we examine the motions of the anterior extremity in different animals, it will guide us to see why in some this bone is perfect, and in others, entirely wanting. Animals which fly, or dig, or climb, as bats, moles, porcupines, squirrels, ant-eaters, armadilloes, and sloths, possess the collar-bone; for having a lateral or outward motion of the extremity, that bone is required to keep the shoulders apart. There is also a degree of freedom of motion in the anterior extremity of the lion, cat, dog, martin, and bear; they strike with the paw, and rotate the wrist more or less extensively; and they have therefore a clavicle, though an imperfect one. In some of these, as the lion, the bone occupying the place of the collar-bone is very imperfect indeed; although attached to the shoulder, it does not extend to the breast-bone (A), but lies concealed in the flesh, and is like a mere rudiment of the bone. Yet, however imperfect, it marks a correspondence in the bones of the shoulder to those of the arm and paw, and the extent of motion enjoyed.

When the bear stands up, we perceive by his ungainly attitude and the movements of his paws, that there must be a wide difference in the bones of his upper extremity from those of the hoofed or cleft-footed animal. He can take the keeper's hat from his head, and hold it; or can hug an animal to death. The ant-bear especially, as he is deficient in teeth, possesses extraordinary powers of hugging with his great paws; and, although harmless in disposition, he can on occasion squeeze his enemy, the jaguar, to death.

These actions, and the power of climbing, result from the structure of the shoulder, from there being a collar-bone, however imperfect.

Although in man the clavicle is perfect, thereby corresponding with the extent and freedom of motion of his hand, yet in some animals which dig or fly, as the mole and bat, the bone is comparatively stronger and longer.

Preposterous as appears the form of the kangaroo, yet, even in this animal, a relation is preserved between the extremities. He sits upon his strong hind-legs and tail, tripod-like, with perfect security; and has his fore-paws free. He has a clavicle, and it is from possessing that bone and the corresponding motions, that he can employ his paws as a means of defence; for with the anterior extremities he will seize the most powerful dog, and then drawing up his hinder feet, dig his sharp-pointed hoofs into his enemy, striking out, and tearing him to pieces. Though possessed, therefore, of no great speed, and unprovided with horns, teeth, or claws, but, as we should suppose, totally defenceless, nature has not been negligent of his protection.*

It cannot be better shown, how the function or use of a part determines its structure, than by looking to the clavicle and scapula of the bird.

The chief peculiarity of birds is, that in flying they do not strike out their wings with an alternate motion, but their extremities, as we may continue to call them, move together. Now, three bones converge to constitute the shoulder-joint of the bird: the scapula, clavicle, and coracoid bone.† But neither the scapula nor clavicle has the resemblance which their names would imply. The scapula is the long thin bone, like the blade

* In the form of the kangaroo, and especially in its skeleton, there is something incongruous, and in contrast with the usual shape of quadrupeds. The head, trunk, and fore-paws appear to be a portion of a smaller animal unnaturally joined to the legs of another of greater dimensions and strength. It is not easy to say what are, or what were, the exterior relations corresponding with the very peculiar form of this animal; but the interior anatomy is accommodated, in a most remarkable manner, to the enormous hinder extremities. The subject is taken up in the "Additional Illustrations" at the latter part of the volume, on the "General Form of the Skeleton."

† In man, the coracoid bone is a *process* of the scapula; but late comparative researches into the "type" of the vertebral skeleton, make it appear that, although joined in man to the shoulder-blade, the coracoid is a distinct elementary bone of the "scapular arch," or basis of the upper extremity.—(S.)

of a knife; and the clavicles are united at the centre, near the breast-bone, to form the furculum, or fork-bone, which, in carving, we detach, after removing the wings of a fowl. This leaves that stronger portion of bone which is articulated with the breast-bone, as a new part; and although it corresponds with the place of the clavicle, yet, from its bearing an *analogy to a process of* the irregularly-formed scapula in mammalia, it is called coracoid bone. However this may be, what we have to admit, is the mode in which the bones are fashioned to strengthen the articulation of the shoulder, and to give extent of surface for the attachment of the muscles which move the wings, as long levers, in flight.

Skeletons of Eagle and Lizard.

OF THE SCAPULA.

By attending to the scapula, or shoulder-blade, we shall better understand the influence of the bones of the shoulder on the motions and speed of animals. The scapula is that flat triangular bone which lies on the ribs, and is cushioned with muscles. On its anterior angle there is a depressed surface, the glenoid cavity or socket for the arm-bone. The scapula shifts and revolves on the ribs with each movement of the arm. To produce these movements, the muscles converge towards it from all sides, from the head, spine, ribs, and breast-bone, and, by acting in succession, they roll the scapula and toss the arm in every direction. When the muscles combine in action, they fix the bone, and either raise the ribs in drawing breath, or give firmness to the whole frame of the trunk.

Before remarking further on the influence of the scapulæ on the motions of the arms, I shall give an instance to prove their importance to the function just referred to, that of assisting in

drawing in the breath. Hearing that there was a poor lad of fourteen years of age born without arms, and whose unhappy condition had excited the benevolence of some ladies, I sent for him. I found that indeed he had no arms, but he had clavicles and scapulæ. When I made this boy draw his breath, the shoulders were elevated; that is to say, the scapulæ, being drawn up, became the fixed points from which the broad muscles diverging from it towards the ribs, acted in raising and expanding the chest in respiration. We would do well to remember this double office of the scapula and its muscles; that whilst it is the foundation of the bones of the upper extremity, and never wanting in an animal that has the most remote resemblance to an arm, yet it is the centre also and *point d'appui* of the muscles of respiration, and acts in that capacity even when there are no extremities at all.*

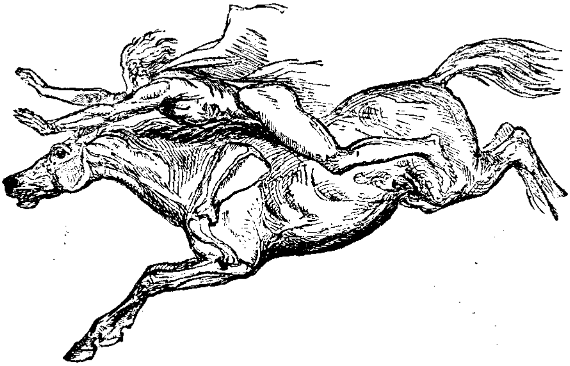
We have seen that it is only in certain classes of animals, that the scapula is articulated to the trunk by bone through the medium of a clavicle. A slight depression, therefore, on that process of the scapula (acromion process, E. fig. p. 32) to which the clavicle is attached, when discovered in a fossil bone, will declare to the geologist the class to which the animal belonged. For example, there are brought over to this country the bones of the Megatherium, an animal which must have been larger than the elephant; of the anterior extremity, the scapula only has been found; but on the end of the process, called acromion, of this bone, the mark of the attachment of a clavicle is discovered. Now that alone points out the whole constitution of the extremity; that it enjoyed perfect freedom of motion. Other circumstances will declare whether that extensive motion was bestowed to enable the animal to dig with its huge claws, like some of the edentata, or to strike out in defence, like the feline tribe.

Some interest is attached to the position of the scapula, in the horse. In him, as well as in other quadrupeds, with the exceptions already pointed out, the clavicle is absent; the connexion between the anterior extremity and the trunk exists solely through muscles: and the muscle called serratus magnus, which is large in man, is particularly powerful in the horse; for

* Some curious facts, illustrative of this office of the muscles of the arm situated on the chest, are stated in the author's paper on the "Voice," in the Philosophical Transactions, 1832.—(S.)

the weight of the trunk hangs almost exclusively upon this muscle.* But the speed of the horse, as in most quadrupeds, results from the strength of his loins and hinder extremities; it is the action of the muscles situated there, which propels him forwards, in the gallop or at the leap. We accordingly perceive that if the anterior extremities had been joined to the trunk firmly, as by a clavicle, that bone could not have withstood the shock from the descent of the whole weight of the animal when thrown forwards. Even though the fore-legs had been formed as powerful as the posterior extremities, they would have suffered fracture or dislocation. We cannot but admire, therefore, this provision, in all quadrupeds whose speed is great and spring extensive, for diminishing the shock of descending, and giving an elasticity to the anterior extremities.

In observing the relative position of the bones of the anterior extremity in the horse, we shall perceive that the scapula is



oblique to the chest; the humerus oblique to the scapula; and the bones of the fore-arm at an angle with the humerus. Were these bones arranged in a straight line, end to end, the shock of alighting would be conveyed as through a solid column; and the bones of the foot, or the joints, would suffer from the concussion. When the rider is thrown forwards on his hands, and

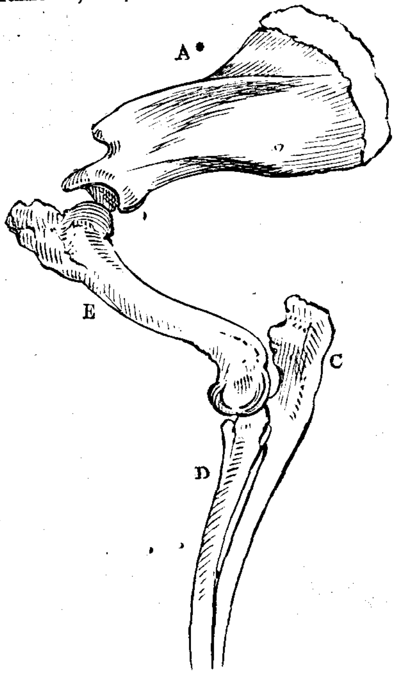
* The serratus magnus, attached extensively to the ribs near the breast-bone, ascends convergingly to the upper border of the scapula, near the withers.

more certainly when he is pitched on his shoulder, the collar-bone is broken; because in man, this bone forms the link of connexion between the shoulder and the trunk, and it accordingly receives the whole shock. Now the same would happen in the horse, the stag, and all quadrupeds of great strength and swiftness, were not the scapulæ sustained by muscles, in place of bone, and did not the bones recoil and fold up.

The horse-jockey runs his hand down the horse's neck, in a knowing way, and says, "This horse has got a heavy shoulder; he is a slow horse!" He may be right, and yet not understand the matter. It is not possible that the shoulder can be too much loaded with muscle, for muscle is the source of motion, and bestows power. What the jockey feels, and forms his judgment on, is the abrupt transition from the neck to the shoulder; while, in a horse for the turf, there ought to be a smooth undulating surface. This abruptness, or prominence of the shoulder, is a consequence of the upright position of the scapula; the sloping and light shoulder results from its obliquity. An upright shoulder is therefore the mark of a stumbling horse: the scapula does not revolve easily, to throw forward the foot.

Much of the strength, if not the freedom and rapidity of motion of a limb, will depend on the angle at which the bones lie to each other; for that mainly affects the insertion, and, consequently, the power of the muscles. We know, and may every moment feel, that when the arm is extended, we possess little power in bending it; but in proportion as we bend it, the power is increased. This is owing to the change in the direction of the muscular force acting upon the bone; or, in other words, to the tendon of the muscle becoming more perpendicular to the lever. A scapula which inclines obliquely backwards, increases the angle at which the humerus, or arm-bone, lies with reference to it: and, consequently, the muscles which pass from it to the arm-bone, will act with greater effect, from being inserted into that bone more nearly at a right angle. We have only to turn to the skeleton of the elephant, the ox, the elk, or the stag, to see the confirmation of this principle. When the scapula lies obliquely on the chest, the serratus muscle, which passes from the ribs to its uppermost part, has more power in rolling it. This direction of the scapula causes it to lie at right angles with the humerus; and, accordingly, the muscles which are attached to the latter

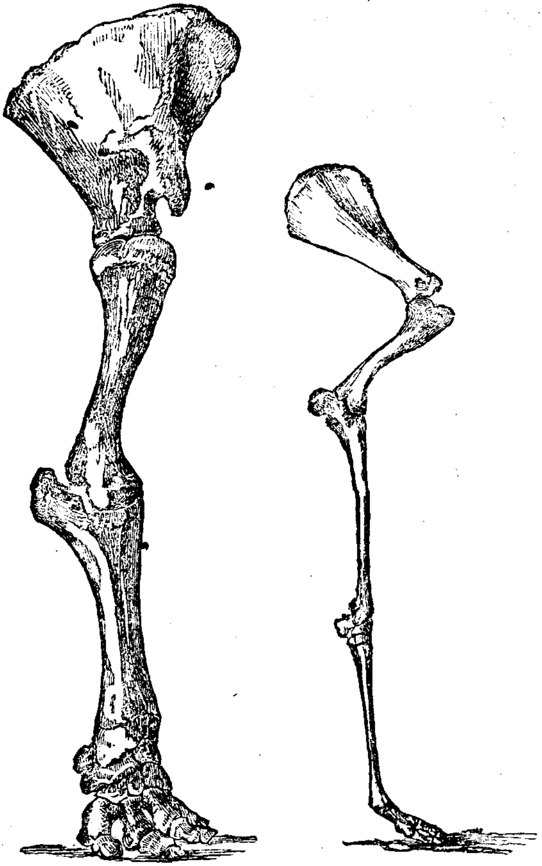
(at B) act with more effect. And on the same principle, by the oblique position of the humerus, and, consequently, its obliquity in reference to the radius and ulna, the two bones of the fore-arm, the power of the muscle inserted (at C) into the olecranon, is increased. On the whole, both power and elasticity are gained by this position of the superior bones of the fore-leg. It gives to the animal that springs a larger stretch in throwing himself forwards, and a greater security, by a soft descent of his weight. A man, standing upright, cannot leap or start off at once; he must first sink down, and bring the bones of his extremities to an angle. But the antelope, or other timid animals of the class, can leap at once, or start off in their course without preparation—another advantage of the oblique position of their bones when at rest.



These sketches with the pen are from the skeletons of the elephant and the camel: and it is obvious that the leg of the former is built for the purpose of sustaining the huge bulk of the animal, whilst in the camel there is a perfect contrast. Were we to compare the bones of the larger animal with any style of architecture, it would be with the Egyptian; or, rather,

* A, Scapula. E, Humerus, or arm-bone. B, Tuberosity of the Humerus. C, Olecranon, or projection of the Ulna. D, Radius.

from their huge and shapeless form, and being piled over each other, as if destined more to sustain weight than to permit mo-

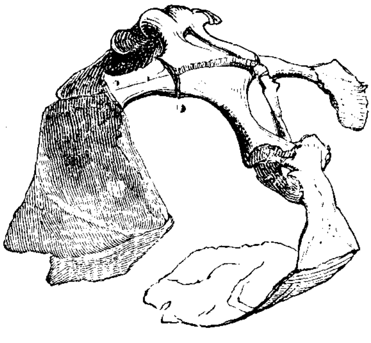


tion, they might be likened to the unwrought masonry in the Cyclopian walls of some ancient city.

We further perceive, from the comparison of these sketches,

that if the humerus be placed obliquely, it must necessarily be short; otherwise the leg would be thrown too far back, making the head and neck project inordinately. It is one of the "points" of a horse to have the humerus short. And not only all animals of speed, but birds of long flight, as the swallow, have the humerus short. This is owing, I think, to another circumstance, that the shorter the humerus, the quicker will be the extension of the wing: for as the further extremity of the bone, when short, will move in a lesser circle, the gyration will be more rapid.

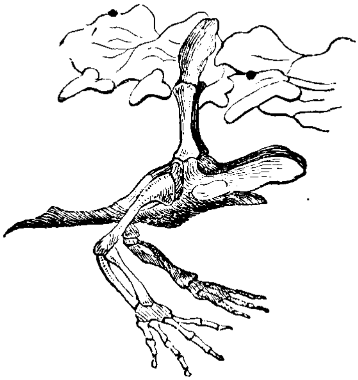
If we continue this comparative view of the bones of the shoulder, we shall be led to notice other curious modifications. In man and mammalia, two objects, we have seen, are attained in the construction of these bones; besides forming the basis for the other bones of the upper extremity, the shoulder-bones constitute an important part of the organ of respiration, and conform to the structure of the chest. But we shall find that in some animals, the latter function is in a manner withdrawn from them; the scapulæ and clavicles are left without the support of the ribs. In order therefore to give due firmness to the shoulder, these bones require additional carpentry; or they must be laid together on a different principle. In the batrachian order,* for example the frog, the mechanism of respiration is altogether distinct from what it is in the mammalia: the thorax, as constituted of ribs, is absent. Accordingly, we find the bones of the shoulder constructed on a new model; they form a broad and flat collar, sufficient to give secure attachment



Scapular Arch of Frog.

* In this figure of the "scapular arch" of the frog, the breast-bone has its lower face upwards. The clavicles and coracoid bones meet in the centre: the broad flat scapulæ join the two latter to form the sockets of the shoulder-joints.

to the extremity, and affording ample space for the lodgment of the muscles which move the arm. Perhaps the best example of that structure is visible in the siren and proteus; where the ribs are reduced to a very few imperfect processes attached to the vertebræ; and where the bones of the shoulder, being deprived, accordingly, of all support from the thorax, depend upon themselves for security.* Here the bones corresponding to the sternum, clavicles, coracoids, and scapulæ, are found clinging to the spine, and, like the pelvis,† forming a circle, to the lateral parts of which the arm-bones are articulated.



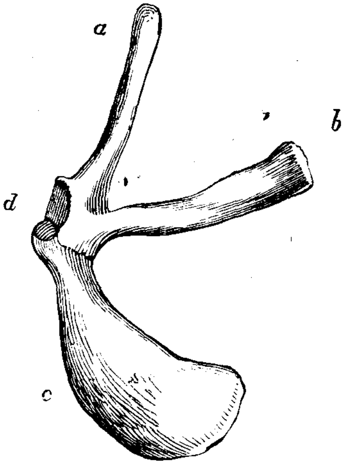
Anterior Extremity of Siren.

In the chelonian order, the tortoises, we see a similar design accomplished by another adjustment, or mode of union of these bones; and the change is owing to a very curious circumstance. The spine and ribs are placed like rafters under the strong shell which forms the covering or carapace of these animals; and being united to this shell, they are consequently external to the bones of the shoulder. Hence the scapulæ and clavicles being within the thorax, instead of outside and supported by it, it is necessary, in order to convert them into fixed points for the motions of the extremities, that they fall together, and form a circle. Indeed, considering the new circumstances in which they are required to act as a basis for the extremity, it would be strange if they preserved any resemblance to the forms which we have been contemplating in the higher animals. In the following figure, the bones of the shoulder of the turtle are represented; and it is readily perceived how much they are changed both in shape and office. The part most like a scapula, lies on

* The Scapula, Clavicle, Sternum, and Coracoid bone, may be recognised in this figure of the bones of the anterior extremity of the Siren.

† The pelvis is the circle of bones on which the spine or back-bone rests, and in which are the sockets for the heads of the thigh-bones.

the fore instead of the back part; and the bones which hold the shoulders apart, abut upon the spine, instead of upon the sternum. Hence it appears idle to describe these bones under the old denominations, or by names applicable to their condition in the higher animals.



Shoulder-bones of Turtle.*

In fishes, although the apparatus of respiration is entirely different from what it is in mammalia, and there are no proper ribs, the bones which give attachment to the pectoral fin are still called the bones of the shoulder. The system of bones named "scapular arch," is, in fact, attached to the skull, instead of to the ribs or spine; so that the structure corresponding to the shoulder, consists of a circle of bones, which, we may say, seeks security of attachment by approaching the more solid part, the head, in defect of a firm foundation in the thorax.†

Thus it has been shown that the bones which form the shoulder-joint, and give a foundation to the anterior extremity, are submitted to a new modelling in correspondence with every variety in the apparatus of respiration; and still they maintain their pristine office.

* *a*, Scapula. *b*, Acromion process. *c*, Coracoid bone. *d*, Glenoid cavity.

† Mr Owen has applied his extensive knowledge of osteology, and philosophical views of the relations of the structure of animals to a general type, to establish some interesting points which bear on questions treated of in these pages. By taking into view the elementary parts which constitute a typical vertebra, and subdividing the cranial bones into four vertebral segments, he has been led, by an able course of induction, embracing the skeletons of animals from the fish to man, to the conclusion—"that the human hands and arms, in relation to the vertebral archetype, are parts of the head; diverging appendages of the costal and hœmal arch of the occipital segment of the skull." See his "Discourse on the Nature of Limbs," 1849.—(S.)

The naturalist will not be surprised on finding in the shoulder apparatus of the ornithorhynchus paradoxus, an extraordinary intricacy; since the whole frame and organs of this animal imply that it is intermediate between mammalia and birds; for which reason it has been placed in the list of edentata. This animal affords another instance of the changes which the bones of the shoulder undergo with every new office, that they may correspond with the motions of the extremity; whether it be to support the weight in running, or to give freedom to the arm, or to provide for flying, or to enable the animal either to creep or to swim.

Unprofitable as the inquiry may seem, there is no other way for the geologist to distinguish the genera of the extinct and strangely-formed oviparous reptiles embedded in the secondary strata, than by studying in the recent species, the minute processes and varying characters of these bones. In the ichthyosaurus, and plesiosaurus, the inhabitants of a former world, there is a considerable deviation from the general type of the bones of the arm and hand, as compared with the same parts in the frog and tortoise; but, if strength were the object, we should say that the bones of the shoulder were formed in these extinct reptiles, with a greater degree of perfection. The explanation is, that the ribs and sterno-costal arches, constituting the thorax, were more perfect in them than in the chelonian and batrachian orders; whence the bones of the shoulder were situated externally, and resembled those of the crocodile. Yet, notwithstanding this superiority, the ribs were obviously not strong enough to sustain the powerful action of the muscles of the anterior extremities, or paddles; accordingly, the bones, which by a kind of licence we continue to call clavicle, omoplate or scapula, and coracoid, though strangely deviating from their original forms and connexions, constitute a structure of considerable strength, which perfects the anterior part of the trunk, and gives attachment and lodgment to the powerful muscles of the paddle.

But it does not appear that naturalists have hit upon the right explanation of the peculiar structure and curious varieties of these bones in the class of reptiles. Why is the apparatus of respiration so totally changed in these animals? They are cold-blooded animals; they require to respire less fre-

quently than other creatures, and they remain long under the water. I conceive that the peculiarity in their mode of respiration corresponds with this property. Hence their vesicular lungs; their mode of swallowing the air, instead of inhaling it; and hence, especially, their power of compressing the body and expelling the air. It is this provision for emptying the lungs, I imagine, which enables reptiles to go under the water and crawl upon the bottom. Had they possessed the lungs of warm-blooded animals, which are compressible only in a slight degree, their capacity of remaining under water would have been of no use; when they dived, they would have had to struggle against their own buoyancy, like a man, or any of the mammalia, when submerged. The girdle of bones of the shoulder is constituted, therefore, with a certain relation to the peculiar action of respiration; inasmuch as the pliancy of the thorax is provided in order that the vesicular lungs may be easily compressed, and the specific weight diminished. The facility which the absence of ribs in the batrachian order affords, for compressing the lungs extended through the abdomen, and the extreme weakness and pliancy of the ribs in the saurians, must be, as I apprehend, peculiarities adapted to the same end.

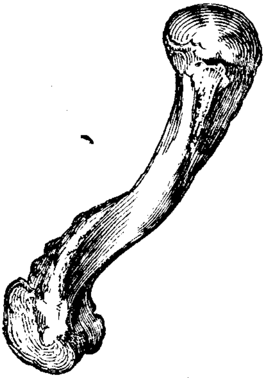
OF THE HUMERUS, OR ARM-BONE.

The demonstration of this bone need not be so dry a matter of detail as the anatomist makes it. From its form may be deduced that curious relation of parts which has been so successfully employed by Paley to prove design, and from which the genius of Baron Cuvier has brought out some of the finest examples of inductive reasoning.

In looking to the head of this bone in the human skeleton, (see the fig. in p. 32,) we observe its great hemispherical surface for articulating with the glenoid cavity or socket of the scapula; and we see that the two tubercles for the insertion of muscles near the joint are depressed, and do not interfere with the revolving of the humerus by striking against the edges of the socket. Such appearances alone are sufficient to show that all the motions of the arm are free.

To give assurance of this, and to illustrate how the form of the shoulder points to the structure of the whole arm, suppose that the geologist has picked up this bone in interesting circum-

stances. To what animal does it belong? The globular form of the articulating surface, and the very slight projection of the tubercles, evince a latitude of motion. Now, freedom of motion in the shoulder implies a similar freedom in the extremity or paw, and a power of rotation of the wrist. Accordingly, we direct the eye to that part of the bone which gives origin to the muscles for turning the wrist (the *Supinator muscles*); and the prominence and the length of the ridge or crest, situated on the lower and outer side, from which these muscles arise, at once prove their strength, and that the paw had free motion.



Arm-bone of Bear.

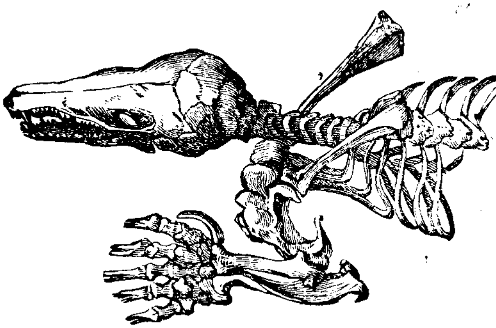
Therefore, on finding the humerus thus characterised, we conclude that it belonged to an animal with sharp moveable claws—that, in all probability, it is the remains of a bear.

But, suppose that the upper head of the bone has a different character: that the tubercles project, so as to limit the motion in every direction but one, and that the articulating surface is less regularly convex. On inspecting the lower extremity of such a bone, we shall perceive that the grooves into which the bones of the fore-arm are socketed, are hollowed out so deeply that the joint could only have the motion of a simple hinge; and neither the form of the articulating surface, (which is here called trochlea,) nor the crest or spine

Arm-bone of Horse.

above noticed on the outside, will present any signs of one bone of the fore-arm having rotated on the other. We have, therefore, got the bone of an herbivorous quadruped, either with a solid or with a cloven foot.

In the bat and mole, perhaps, the best examples are seen of the bones of the extremity being moulded to correspond with the condition of the animal. The mole is fitted, by means of

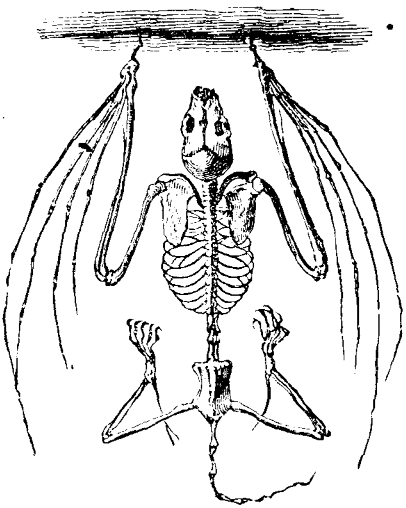


From the Mole.

its anterior extremities, to plough its way under-ground. The bat has the same system of bones; but they are adapted to form a wing for raising the animal in the atmosphere, and with a provision for its clinging to the wall, although not to bear upon it. In both these animals we recognise every bone of the upper extremity; but how very differently formed and joined! In the mole, the sternum, or breast-bone, and the clavicle, are remarkably large: the scapula, or shoulder-blade, assumes the form of a high lever: the humerus is thick and short, and has such prominent spines for the attachment of muscles as to indicate great power. The spines which give origin to the muscles of rotation, project in an extraordinary manner; and the hand is large, flat, and so turned that it may shove the earth aside like a ploughshare.*

* The snout may vary in its internal structure with new offices. Naturalists say that there is a new "element" in the pig's nose: *and it* has, in fact, two bones which admit of motion, whilst they give more strength in digging up the ground. As moles plough the earth with their snouts,' they likewise have these bones, and their head is shaped like

There can be no greater contrast to these bones of the mole than is presented in the skeleton of the bat. In this animal the bones are light and delicate; and whilst they are all marvellously extended, the phalanges, or the rows of bones of the fingers, are elongated so as hardly to be recognised, obviously for the purpose of sustaining the membraneous web, and to form a wing.

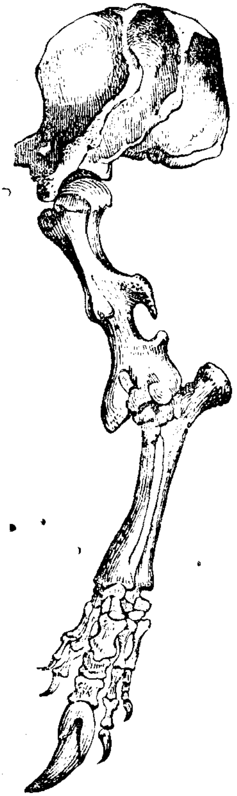


Skeleton of Bat.

Contemplating this extraordinary application of the bones of the upper extremity in the bat, we might be led to say, on comparing it with the wing of a bird, that it was an awkward attempt—"a failure." But before giving expression to such an opinion, we must understand the objects required in this construction. The wing of the bat is not intended merely for flight: it is so formed that while it can sustain the animal in flying, it shall be capable also of receiving a new sensation on its surface, or sensations of such an exquisite degree of fineness as almost to constitute a new sense. On the thin web of the bat's wing numerous nerves are distributed; and the use of these is to enable the animal, during the obscurity of night, when both eyes and ears fail, to avoid objects in its flight. Could the wing

a wedge, to assist in burrowing and throwing aside the earth. The conformation of the head, and the strength of its bones, and the new adjustment of the muscle (the *platysma myoides*), which is cutaneous in other animals, to assist in moving the head, are among the curious changes of common parts for enabling them to perform new offices. See again the "Additional Illustrations" in the Appendix.

of a bird, covered with feathers, do this? Here then we have another example of the necessity of taking every circumstance into consideration before presuming to criticise the ways of nature. It is a lesson of humility.*



We have here a sketch of the arm-bone of the Ant-eater, † to show once more the correspondence maintained throughout all the parts of an extremity. We observe these extraordinary spines standing off from the humerus. Now, these indicate the power of the muscles attached to the bone; for, as I have said before, whether we examine the human body, or the forms of the bones in the lower animals, the distinctness with which the spines and processes are marked, declares the strength of the muscles. It is particularly pleasing to notice here the correspondence between the humerus and all the other bones, — how large, in the first place, the scapula is, and how it has a double spine, with great processes : how remark-

* Besides the adaptation of the bat for flight, by the adjustment of the bones of its arm, this animal has a series of cells situated under its skin. I know not whether I am correct or not in saying that these are analogous to the air-cells of birds, and serve to make the bat specifically lighter. In some species they extend over the breast, and into the arm-pits, and are filled by an orifice which communicates with the throat.

I have adverted to the provisions in the bones of the shoulder of the bird to give firmness to the joint, seeing that it is the centre of motion for the wing. Now, although the bat has not the same arrangement of bones as the bird, yet the clavicles are remarkably strengthened : and the articulation of the arm-bone upon the shoulder-blade is guarded by processes in such a manner that the motion of the joint is extremely limited.

† Tamandua, from South America.

ably the ulna projects at the olecranon or elbow, while the radius is still free for rotating: but above all, we cannot fail to observe in the development of one grand metacarpal bone and its corresponding phalanges, to the last of which a strong claw is attached, a most efficient instrument for scratching and turning aside an ant-hill. The whole, therefore, is an example of the relation of the particular parts of the extremity to one another; and were it our business, it would be easy to show that as there is a correspondence among the bones of the arm, so is there a more universal relation between those of the whole skeleton. As the structure of the bones of the arm declares the extremity to be adapted for digging into ant-hills, so we shall not be disappointed in our expectation of finding that the animal has a projecting muzzle unarmed with teeth, and a long tongue provided with a glutinous secretion, to lick up the emmets disturbed by its scratching.

In the skeleton of the Cape-mole, we may see, in the projection of the acromion scapulæ, and a remarkable process in the middle of the humerus, a provision for the rotation of the arm; which implies burrowing. But the apparatus is by no means so perfect as in the common mole; so that we may infer that the Cape-mole digs in a softer soil, whilst the possession of gnawing teeth indicates that it subsists on roots.

In BIRDS, there is altogether a new condition of the osseous system, as there is a new element to contend with. The very peculiar form and structure of their skeleton may be thus accounted for. First, it is necessary that birds, as they are buoyed in the air, should be specifically light; secondly, the capacity of their chest must be extended, and the motions of their ribs limited, so that the muscles of the wings may have sufficient space and firmness for their attachment. Both these objects are attained by a modification of the apparatus for breathing. The lungs are highly vascular and spongy, but they are not capable of being distended with air; the air is drawn through their substance, passing, by means of numerous orifices, into cells under their skin, and even filling the interior of their bones; so that whilst the great office of decarbonisation of the blood is securely performed, advantage is taken to let the air, warmed and rarefied by the high temperature of their bodies, into all their cavities.

From what was said, in the introductory chapter, of the weight of the body being a necessary concomitant of muscular strength, we see why the lightness of the bird, as well as the conformation of its skeleton, may be a reason for its walking badly. On the other hand, in observing how that lightness is adapted for flight, it is remarkable what a small addition to the weight will prevent the bird from rising on the wing. If the griffon-vulture be scared after his repast, he must disgorge before he can fly; and so with the condor,—if found in the same circumstances, he can be taken by the Indians, like a quadruped, by throwing the lasso over his neck.*

As every one must have observed, the breast-bone of the bird extends the whole length of the body, covering the great cavity, common to the chest and abdomen, into which the air is admitted. Now, it follows from this extension of the breast-bone, that a lesser degree of motion suffices for respiration; accordingly, a greater surface is obtained for the lodgment and attachment of the muscles of the wings, whilst that surface being less disturbed by the action of breathing, is more steady. Another peculiarity of the skeleton of the bird is, that the vertebræ, instead of being moveable on each other, are consolidated: an additional proof, if any were now required, of the whole system of bones conforming to that of the extremities; because, to give effect to the action of the muscles of the wings, it is necessary that all the bones of the trunk to which they are attached should be united firmly together.†

From the vertebræ of the bird being thus fixed, and the pelvis reaching high, no motion can take place in the body; indeed, if there were any mobility in the back, it would be interrupted by the sternum or breast-bone. We cannot but admire, therefore, the structure of the neck and head; how the length and pliability of the vertebræ of the neck not only give to the bill the extent of motion and office of a hand, but, by enabling the bird to preserve its balance in standing, running, or flying, become a substitute for the loss of flexibility in the body. Is it not curious to observe how the whole skeleton is adapted to this one object, the power of the wings!

Whilst the ostrich and other "runners" have not got a *keel*

* The subject is continued in the "Additional Illustrations."

† The ostrich and cassowary, which are runners, have the spine loose.

in their breast-bone, birds of passage are recognisable by the depth of the ridge of the sternum. The reason is, that the

angular space formed by that process and the body of the bone affords lodgment for the pectoral muscle, the powerful muscle of the wing. In this sketch of the dissection of the swallow there is a curious resemblance to the human arm; and we cannot fail to observe that the pectoral muscle constitutes the greater part of the bulk of the body.* And here we perceive the correspondence between the strength of this muscle and the rate of flying of the swallow, which is a mile in a minute, for ten hours every day, or six hundred miles a day.† If it be true that birds, in migrating, require a wind that blows against them,‡ it implies an extraordinary power, as well as continuance, of muscular exertion.

* Borelli makes the pectoral muscles of a bird exceed in weight all the other muscles taken together; whilst he calculates that in man the pectoral muscles are but a seventieth part of the mass of muscles.

† Mr White says truly that the swift lives on the wing; it eats, drinks, and collects materials for its nest while flying, and never rests but during darkness. No bird equals the humming-bird in its powers of flight, and, accordingly, it has a broader sternum, and a greater prominence of keel, in proportion to its size, than any other bird. It may be mentioned, that in the sternum of the bat a very distinct ridge is developed, corresponding with the keel of the bird.

‡ It is possible that the wind blowing near the ground in one direction, may be attended with a current of a higher stratum of the atmosphere in

We thus see how Nature completes her work when the animal is destined to rise buoyant and powerful in the air :—the whole texture of the frame is altered, and made light in a manner consistent with strength; the mechanism of the anterior extremity is changed, and the muscles of the trunk are differently directed. But we are tempted to examine other instances, where the means, we would almost say, are more awkwardly suited for their purpose; that is, where the system of bones and muscles peculiar to the quadruped being preserved, the animal has still the power of launching into the air. We have already noticed how the structure of the bat is adapted to flight; but there are other animals, differing from birds more widely than it, which enjoy the function, though in a lesser degree. For example, the flying squirrel (*Pteromys volucella*), being chased to the end of a bough, spreads out the mantle which reaches along both its sides from the anterior to the posterior extremity, and drops in the air; and during its descent, it is met by such a resistance of the air from its extended skin and bushy tail, that it can direct its flight obliquely, and even turn, without any adaptation of the anterior extremity. Among reptiles, a provision of the same kind exists in the Draco fimbriatus; which, after creeping to a height, can drop safely to the ground, under the protection of a sort of parachute, formed by its extended skin. This is no inapt illustration: it is not the bones of the fingers that are here used to extend the web; but the ribs, which are unnecessary, in this animal, for breathing, are prolonged in a remarkable manner, like the whalebones of an umbrella, and upon them the skin is expanded.

This brings us to a very curious subject,—the condition of some of those Saurian reptiles, the remains of which are found only in a fossil state, most abundantly in the lias and oolite, termed the ancient strata of the Jura. The Pterodactyle of Cuvier is an animal which seems to confound all our notions of system. A lizard, yet its mouth was like the long bill of a bird, and its flexible neck corresponded; but it had teeth in its jaws like those of a crocodile. The bones of the anterior extremity were elongated, and fashioned somewhat like those in the wing

a contrary direction, and that the idea of migrating birds flying against the wind may have arisen from that mistake.

of a bird; but it could not have had feathers, as it had not a proper bill; we see no creature with feathers that has not a bill with which to dress and preen them. Nor did the extremity resemble that of a bat in structure: instead of the rows of bones being equally prolonged in all the fingers, as in the bat, the second finger only was extended to an extraordinary length; whilst the third, fourth, and fifth had the size and articulations of those of a quadruped, and were terminated with sharp nails corresponding to the pointed teeth. The extended bones reached to double the whole length of the animal, and the conjecture is, that a membrane, resembling that of the Draco fimbriatus, was expanded upon them. In the imperfect specimens upon which we have to found our reasoning, we cannot discover, either in the height of the hip-bones, the strength of the vertebræ of the back, or the expansion of the breast-bone, a provision for the attachment of muscles commensurate with the extent of the supposed wing. The arm-bone and the bones which we presume to be the scapula and coracoid, bear some correspondence to the extent of the wing: but the extraordinary circumstance of all is the size and strength of the bones of the jaw and vertebræ of the neck, compared with the smallness of the body and the extreme delicacy of the ribs; which makes this altogether a being the most incomprehensible in nature.

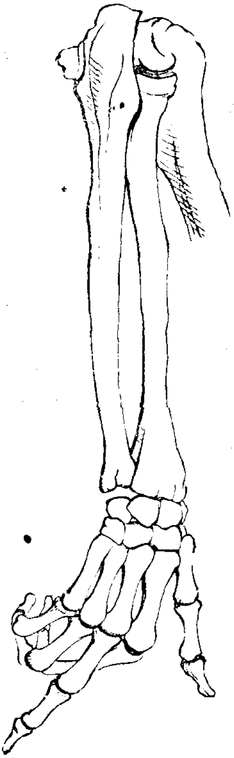
OF THE RADIUS AND ULNA.

The easy motion of the hand, we might imagine to result from the structure of the hand itself; but, on the contrary, the movements which appear to belong to it, are divided among all the bones of the extremity.*

The head of the arm-bone is rotatory on the shoulder-blade, as when making the guards in fencing; but the easier and finer rolling of the wrist is accomplished by the motion of one bone of the fore-arm upon the other. The ulna has a hooked process, the olecranon, or projecting bone of the elbow, which catches round the lower end of the arm-bone (this articulating portion being called trochlea), and forms with it a hinge joint, for bending and extending the fore-arm. The radius, again, at the elbow, has a small, neat, round head, which is bound to the

* In the sketch (p. 55) the bone with the hand joined to it is the radius; in revolving on the lower bone, the ulna, it carries the hand with it.

ulna by ligaments, as a spindle is held in the bush; and it has a depression with a polished surface for revolving on the condyle of the humerus; at the wrist it has also a surface adapted for rotation: accordingly the radius turns on its long axis, rolling upon the ulna both at the elbow and wrist-joint; and, as *it turns, it carries* the hand with it, because the hand is strictly attached to its lower head alone. This rolling is what are termed pronation and supination.



Such freedom of motion, in an animal with a solid hoof, would be useless, and a source of weakness; hence, in the horse, the radius and ulna are united, and consolidated in the position of pronation.

But before taking any particular instance, let us extend our views. There is, indeed, something so highly interesting in the conformation of the whole skeleton of an animal, and the adaptation of each part to all the others, that we must not let our reader remain ignorant of the facts, and the more important conclusions drawn from them. What we have to state has been the result of the studies of many comparative *anatomists*; but none has seized upon it, with the privilege of genius, in the masterly manner of Cuvier.

Suppose a man, ignorant of anatomy, to pick up a fragment of bone in an unexplored country; he learns nothing, except that some animal has lived and died there; but the anatomist, judging from that portion of bone, can not merely estimate the size of the extremity of the animal as well as if he saw the print of its foot, but he can predicate the form of the joints of the skeleton, the structure of its jaws and teeth, the nature of its

food, and its internal economy. This, to one unacquainted with the subject, must appear wonderful; but it is after the following manner that the anatomist proceeds. Let us suppose that he has taken up that portion of bone, in the limb of a quadruped, which corresponds to the upper part of the human radius; and that he finds that the form of the end of the bone, where it enters into the joint, does not admit of the free motion, in various directions, possessed by the paw of the carnivorous creature. It is obvious, on that view of the structure alone, that the office of the limb must have been for supporting the animal, and for progression, not for seizing prey. That leads him to the fact, that the bones corresponding to those of the hand and fingers, must have differed from the bones of the paw of the tiger; for the motions which that conformation permits, would be useless without rotation of the wrist: and he concludes, therefore, that the hand and finger-bones were each formed in one mass, like the cannon, pastern, and coffin bones of the horse's foot.* Now, the motion of the foot of a hoofed animal being limited to flexion and extension, it implies restrained motion at the shoulder-joint, and absence of a collar-bone. And thus, from the broken specimen in his hand, the naturalist acquires a perfect notion of the bones of both extremities. But the motion of the extremities implies a particular construction of the vertebral column which unites them; each bone of the spine will be of that form which corresponds to the bounding of the stag, or galloping of the horse; but will not have the kind of articulation which admits of the turning or writhing of the body, as in the leopard or tiger.

Next he comes to the head:—and he argues that the pointed, cutting teeth, with which a carnivorous animal is provided to rend its prey, would be useless, unless there were mobility of the extremities, like that of the hand, for grasping it, and claws for securing it. He considers, therefore, that the front teeth must have been for browsing, and the back teeth for grinding. But the socketing of the teeth requires a peculiar shape of the jaw-bones, and the muscles which move these bones must also be peculiar. In short, from the shape and functions of the

* These are solid bones, in which it is difficult to recognise any resemblance to the bones of the hand and fingers; yet comparative anatomy proves that they are analogous.

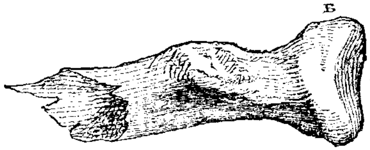
mouth, he forms a conception of the figure of the skull. From that point he may set out anew; for from the form of the teeth, he may deduce the nature of the stomach, the length of the intestines, and all the peculiarities which mark a vegetable feeder, as contrasted with one of the carnivora.

Thus the whole parts of the animal system are so connected with one another, that from one single bone or fragment of bone, be it of the jaw, or of the spine, or of the extremity, a really accurate conception of the shape, motions, and habits of the animal may be formed.

It will readily be understood that by the same process of reasoning, we may ascertain, from a small portion of a skeleton, the existence of a carnivorous animal, or of a fowl, or of a bat, or of a lizard, or of a fish. And what a conviction is here brought home to us of the extent of that plan, which, pervading the whole range of animated beings whose motions are conducted by the operation of muscles and bones, yet adapts the members of every creature to their proper office!

After all, this is but a part of the wonders disclosed through the knowledge of an object so despised as a fragment of bone. It carries us into another science. The knowledge of the skeleton not only teaches us the classification of animals now alive, but affords proofs of the former existence of animated beings which are no longer found on the surface of the earth. We are thus led from such premises to an unexpected conclusion. Not merely do we learn that individual animals, or races of animals, now extinct, existed at those distant periods: but even the changes which the globe has undergone, in time before all existing records, and before the creation of human beings to inhabit the earth, are opened to our contemplation.

To return to our particular subject,—we readily comprehend how, if the geologist should find the head of a radius, resembling this sketch, and see a smooth depression (A), on its extremity, where it bears against the humerus, and a polished circle (B), where it turns on the cavity of the ulna, he would say,—this animal had a paw—it had a motion



Upper End of a Radius.

at the wrist, which implies claws. But claws may belong to two species of animals: to the feline, which possess sharp carnivorous teeth; or to animals without either canine or cutting teeth, the edentata. If he should also find the lower extremity of the same bone, and observe on its surface spines and grooves, the marks of tendons, which, instead of running straight to be inserted into a single bone, radiated to distinct phalanges,—he would conclude that there must have been moveable claws, that the bone must have belonged to a carnivorous animal; and he would seek for canine teeth of corresponding size.

THE LAST DIVISION OF THE BONES OF THE ARM.

In the human hand, the bones of the wrist (carpus) are eight in number; and they are so closely connected that they form a sort of ball, which moves on the end of the radius. Beyond these, and towards the fingers, forming the palm of the hand, are the five metacarpal bones, which diverge at their further extremities, and give support to the bones of the thumb and fingers. In the thumb, the first phalangeal bone is absent. There are thus in the hand twenty-seven bones; from the mechanism of which result strength, mobility, and elasticity.

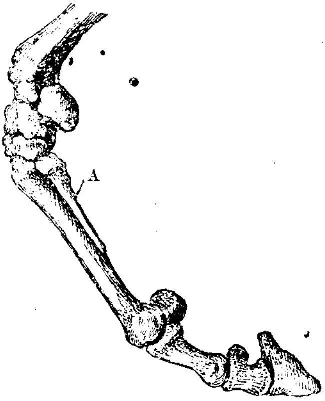
Lovers of system (I do not use the term disparagingly) delight to trace the gradual subtraction of the bones of the hand. Thus, looking to the hand of man, they see the thumb fully formed. In the monkeys (simiæ) they find it exceedingly small; in one of them, the spider-monkey (see page 13), it has almost disappeared, and the four fingers are sufficient, with hardly the rudiments of a thumb. In some of the tardigrade animals, as we have seen (in page 20), there are only three metacarpal bones, with three fingers. In the ox, the cannon-bone consists of two coalesced metacarpal bones, and the double hoofs are supported by the corresponding phalangeal bones. In the horse, the cannon-bone is a single metacarpal bone, and the great pastern, little pastern, and coffin or hoof bone, represent a single finger.* Indeed, we might go further and instance the wing of the bird. To me, this appears to be losing the sense, in the love of system; there is no regular gradation, but, as I have often to repeat, a variety, which most curiously adapts the same system of parts to every necessary purpose.

* See Owen on the Nature of Limbs, p. 32.—(S.)

In a comparative view of these bones, we are led more particularly to take notice of the foot of the horse. It is universally admitted to be of beautiful design, and calculated for strength and elasticity, and especially provided against concussion.

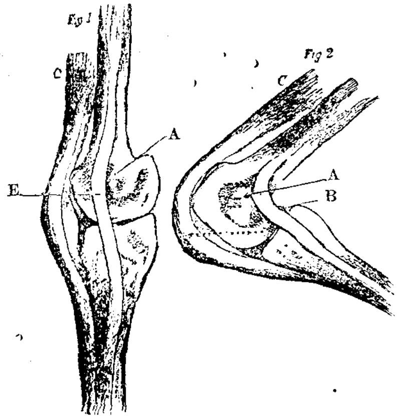
The bones of the fore-leg of the horse become firmer as we trace them downwards. The two bones corresponding to those of the fore-arm, are braced together and consolidated; and the motion at the elbow-joint is limited to flexion and extension. The carpus, forming what by a sort of licence is called the knee, is also newly modelled; but the metacarpal bones and phalanges of the fingers are totally changed, and can hardly be recognised. When we look in front, instead of the four metacarpal bones, we see one strong bone, the *cannon-bone*; and posterior to this, we find two lesser bones, called splint-bones.

The heads of these lesser or splint-bones enter into the knee-joint (or properly the wrist-joint); at their lower ends they diminish gradually, and they are held by an elastic ligamentous attachment to the sides of the cannon-bone. I have some hesitation in admitting the correctness of the opinion held by veterinary surgeons, on this curious piece of mechanism; they imagine that these moveable splint-bones, by playing up and down as the foot is alternately raised and pressed to the ground, bestow elasticity and prevent concussion. The fact certainly is that by over action, the parts become inflamed, and these bones are eventually united to the greater metacarpal or cannon-bone; and that this, which is called a splint, is a cause of lameness. I suspect, rather, that in the perfect state of the joint, these lesser metacarpal or splint-bones act as a spring, to assist in throwing out the foot, when the knee-joint is bent, and the



Bones of Horse's Fore-leg.

extensor muscles begin to act. If we admit that it is on the quickness of extension of the joint that the rate of motion must principally depend, it will not escape observation, that in the bent position of the knee, the extensor tendons, from running near the centre of motion, have very little power; and that, in fact, they require some additional means to aid the extension of the leg. Suppose the head of the splint-bone (A) enters into the composition of the joint, it does not appear that when the leg is straight and the foot on the ground, the bones of the carpus, sustained as they are by the cannon-bone, can descend and press upon it, so as to bring its elasticity into action. But, in the bent position of the knee, the head of the splint-bone will come in contact with the carpal bones, behind the centre of motion of the joint; and it is obvious, therefore, that, when the foot is elevated and the knee bent, the splint bone will be depressed, in opposition to its elastic connecting ligament; so that, as soon as the action of the flexor muscles ceases, it will recoil, and thereby assist the extensor muscles in throwing out the leg into the straight position. Further, we can readily believe that when the elasticity of these splint-bones is lost, by ossification uniting them firmly to the cannon-bone, the want of such a piece of mechanism, essential to the quick extension of the foot, will cause lameness, and make the horse apt to come down.



Hock-joint of the Ostrich.

The mechanism of the bones and tendons of the extremities is infinitely varied; and we hardly ever discern anything uncommon in the outward configuration of an animal, but we find something new and appropriate in the anatomy. The gait, or rather strut, of the ostrich is peculiar; and it results from a very singular

mechanism, a *spring joint*, at the part corresponding with the hock.*

OF THE HORSE'S FOOT.—On looking to the sketch (page 59), and comparing it with that of the bones of the hand (page 55), we see that in the horse's fore-leg, five bones of the first digital row are represented by the large pastern-bone; those of the second by the lesser pastern, or coronet; and those of the last by the coffin-bone.

For illustrating the general subject of our treatise, nothing is better suited than the horse's foot: it is a most perfect piece of mechanism. And whilst examining it, we are impressed with the peculiarity of living mechanism,—that it can be preserved perfect only by the natural exercise of its parts. The horse, originally a native of extensive plains and steppes, has a structure admirably conformed to these his natural pasture-grounds. But when brought into subjection, to run on hard roads, the foot suffers from concussion. His value, so often impaired by lameness, has made the structure of the horse's foot an object of great interest; and I have it from the excellent professor of veterinary surgery to say, that he has never demonstrated the anatomy of this part without perceiving something new to admire.

The weight and power of the animal require that both strength and elasticity should be combined in his foot. Hence the first thing that attracts attention is the position of the bones. Had they been placed one directly over the other,

* The figures (p. 60) illustrate the structure referred to. There is a gentle rising of the bone at A, having a smooth lubricated surface, and a groove in front and behind. In the straight position, the lateral ligament B is lodged in the deep groove at the back of the tubercle; but as the leg is bent, the ligament glides upon the tubercle, it becomes more and more stretched till it reaches the highest point of the convexity, and then it slips, with a jerk, into the shallower groove in front: as the leg is extended, the ligament is again stretched on passing over the tubercle, and falls back, with another jerk, into the groove behind. This play of the ligament over the tubercle, as over a double-inclined plane, is accompanied, at each sliding movement, with a sudden start of the joint, both in flexion and extension; and it is that which gives rise to the peculiar strut of the animal. The object of the structure seems to be to knit or support the joint, when the bird is resting on the limb; and also, in flexion of the joint, to facilitate that great projection of the superior bone backwards, as seen in fig. 2, by which additional power is given to the muscle C, that propels the bird in its course. See Chapter IV.

there could not have been elasticity; accordingly, they are disposed obliquely, and a strong elastic ligament runs behind, terminating by an attachment to the lowest or coffin-bone. So essential is the obliquity of the bones to the elasticity of the limb, that without mounting a horse, it is possible, by observing the direction of the pastern and coffin-bones, to say whether he goes easily or not.*

The bones of the foot of the camel rest on a soft elastic cushion. In the horse's foot, there is a structure of a similar kind, but it acts very differently, and never comes to the ground; nor, indeed, does the sole of the horse's foot directly bear the weight. The horny frog, the triangular projection in the hollow of the hoof, has placed above it an elastic frog or cushion; and inasmuch as these parts receive the weight of the animal, and by their descent, when the foot is on the ground, press out the crust or horny hoof, they are essential to the structure of the foot. The anterior tip of this crust, or the part of the hoof which last touches the ground as the foot rises, is very dense and firm, to withstand the pressure and impulse forward: the lateral parts, however, are elastic, and on their play depends that resiliency of the foot which prevents concussion. The crust is not consolidated with the bone called coffin-bone; certain elastic laminæ, growing from the bone and dovetailed into the crust, are interposed between them. When the animal puts his foot to the ground, the weight bears on the coffin-bone, and from its being attached to the circle of the crust by these elastic laminæ, the lateral parts yield, and the weight is directed on the margins of the crust; the sole never touching the ground, unless it has become diseased.

Xenophon, speaking of the Persian horses, says that their grooms were careful to curry them on a pavement of round stones, that by beating their feet against a firm and irregular surface, the texture of the foot might be put into exercise. It corresponds curiously with this, that our high-bred horses are

* The arched form of the bones, at the fetlock, with their convexity backwards, and the distinctness of the elastic ligament and tendons behind the cannon-bone, can be perceived by the eye and the hand, and constitute one of the "points" of a horse. Such is the correspondence between the strength of an animal's bones, tendons, and muscles, that from these sinews the jockey can infer the perfection or defect of the whole.

subject to a disease of the foot, from which the powerful draught and Flanders horses are exempt. The heavy horse, with less blood than the race horse, lifts its foot in a circle, and comes forcibly on the ground: whilst the horse for the turf, being light, moves with the foot close to the ground; no time is lost in lifting it high in the semicircle; the consequence of which is, that from the foot coming thus gently down, it wants the full play of the apparatus. Hence it may be understood how the lighter horse is subject to contractions of the foot; the bones, ligaments, and crust being out of use, the sole becomes firm as a board, the sides of the crust are permanently contracted, the parts have no longer their elastic play, and the foot striking on hard pavement suffers a shock or concussion; then comes "a fever of the foot," which is inflammation, and that may go on to the total destruction of the fine apparatus. The proof of all this is, that unless the inflammation has advanced too far, by paring and softening the exterior of the hoof, so as to restore its elasticity, the veterinary surgeon may cure this contracted foot.

That a relation should exist between the internal structure of the foot and its covering, whether it be nail, or cloven hoof, or crust, we can hardly doubt: and an unexpected proof offers itself in the horse. Some rare instances are recorded of the foot of the horse having digital extremities. According to Suetonius, there was such an animal in the stables of Cæsar; another was in the possession of Leo X.; and Geoffroy St Hilaire states that he saw a horse with three toes on each of the fore-feet, and four on the hind.* In all these, the toes had nails, not hoofs. By such examples of deviation from the natural structure, it is made to appear still more distinctly, that a relation is established between the internal configuration of the fingers or toes and their coverings,—that when there are five complete, as in man, they are provided with perfect nails,—when the number is two, as in the cleft foot of the ruminant, there are appropriate horny coverings,—and when the bones are reduced to form one, as in the horse, couagga, zebra, and ass, there is a hoof or crust.

In ruminants, there is the cannon-bone; but they have the

* Such a horse was not long since exhibited in Town, and at Newmarket.

to two parts, and that must add to the spring or
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soft ground, and then permits it to be more easily
We may observe how much more easily the cow
foot from the yielding margin of a river, than the
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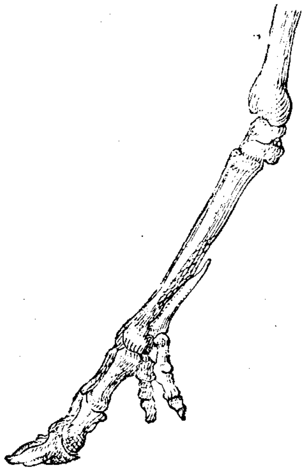
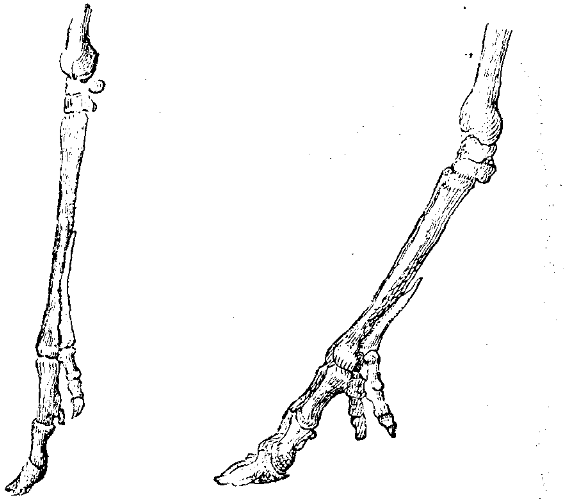


foot split into two parts, and that must add to the spring or elasticity. I am inclined to think that still another intention is manifest in this form of the foot: it first prevents it from sinking into soft ground, and then permits it to be more easily withdrawn. We may observe how much more *easily the cow* liberates her *foot* from the yielding margin of a river, than the horse; the solid, round, and concave foot of the horse is resisted, as it is withdrawn, by a vacuum or suction; while the split and conically-shaped hoof of the cow expands in sinking, and is easily extricated.

In the foot of the chamois, and other species of the deer tribe, there are two additional toes. These sketches show that



Foot of Antelope. *Foot of Reindeer.*

the metacarpal bones, (which in the horse are connected as splint-bones with the joint called the "knee,") are here brought down near to the foot, and that each has its two pasterns, and coffin or ungual bone. The toes are braced by ligaments, which give great elasticity, as well as power of expansion, to

the foot; and as a division of the flexor tendon runs to each, the spring must be increased as the animal starts from its crouching posture.

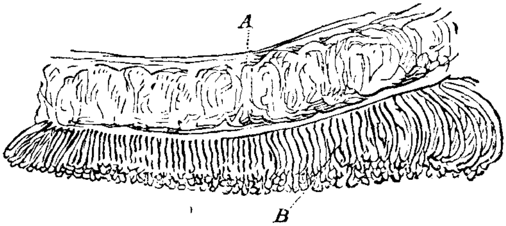
The two lateral toes of the hog are short, and do not touch the ground, yet they must serve to sustain the animal when the foot sinks. In the rein-deer, (fig. p. 64,) these toes are strong and thick, and by projecting backwards, expand the foot horizontally—thus giving the animal a broader base on which to stand, and, on the principle of the snow-shoe, adapting it to the snows of Lapland. These changes in the size, number, and place of the metacarpal and phalangeal bones, the systematic naturalist will call "gradations;" I see only new proofs of *adaptation*,—of the same system of bones being applicable to every circumstance or condition of animals.

I have explained why the bones of the elephant's leg should stand so perpendicularly over each other; but there is also a peculiarity of structure in the bones of its foot. In the living animal, we see only a round pliant mass as a foot, resembling the base of a pillar, or that of the trunk of a stately tree. But when we examine the bones, we find the carpus, metacarpus, and phalanges applied to a very different use from what we have hitherto noticed; they are not connected with a moveable radius, and have no individual motion, as in the carnivorous animal—they serve merely to expand the foot, and give to the broad base of the column a certain elasticity.

In the sketch (page 40) I have placed the bones of the anterior extremity of the camel in contrast with those of the elephant. The camel's foot having no such disproportionate weight to bear as that of the elephant, lightness of motion is secured by the oblique direction of its bones, as well as by the position of the bones of the shoulder, which we have already noticed. But there is much to admire besides in the foot of the camel; although the bottom be flat and hard, like the sole of a shoe, yet, between the tendons and the horny sole, a cushion is interposed, so soft and elastic that the animal treads with the greatest lightness and security.

The resemblance of the foot of the ostrich to that of the camel has not escaped naturalists. In the bird, the same softness and pliancy of the sole are provided for by means resembling those in the quadruped, but by another adaptation of the

frog or elastic pad.* We also have *our* pads; the best, though not the only, example of which is in the heel. The elastic struc-



Sole of the Ostrich's Foot.

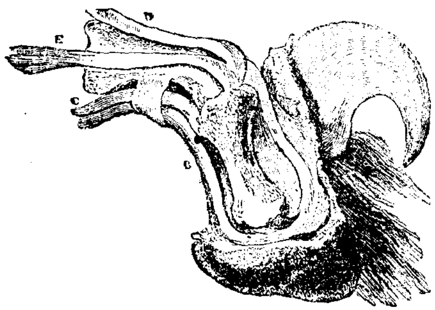
ture interposed between the bone of the heel and the integument, is neither ligamentous, nor cartilaginous, nor fatty, but a happy union of all; elastic fibres are so interwoven with the softer matter, that the cushion gradually yields to our weight, and rises as we step.

Attending still to the last bones of the fingers, let me point out once more how much may be accomplished, in bodying forth the whole animal, by the study of one of these bones. I allude to the dissertations of the President Jefferson and of Baron Cuvier, on the Megalonix. I must previously make some remarks on the mechanism of the claws in the lion.

Animals of the canine tribe, like those of the feline, are carnivorous, and both have the last bones of their toes armed with nails or claws. But their habits and means of obtaining food differ. The canine combine a keen sense of smelling with the power of continued speed; they run down their prey: the feline owe their superiority to the fineness of their sight, accompanied by patience, watchfulness, and stealthy movement; they spring upon their prey, and never long pursue it; they attain their object in a few bounds, and, failing, sulkily resume their watch. When we look to the claws, we see a correspondence with those habits. The claws of the dog and wolf are coarse and strong, and bear the pressure and friction incident to a long chase; they are calculated to sustain and protect the foot. But the tiger

* A, the frog or elastic pad, in the ostrich's foot. B, processes from the horn or cuticle, disposed like the hair of a brush, and forming an adhesive and elastic sole.

leaps on his prey, and fastens his sharp and crooked claws in the flesh. Now, we must admire the mechanism by which they are preserved thus curved and sharp at their points. The last bone, that which supports the claw, is placed laterally to the next bone, and is so articulated with it that an elastic ligament (A) draws it back and to one side, and thus raises the sharp extremity of the claw upwards, and preserves it in that position. Whilst, therefore, the claw is retracted as into a sheath between the toes, the nearer extremity of the furthest bone presses the ground, in the ordinary running of the animal. But when he makes his spring and strikes, the claws are uncased by the action of the flexor tendons; and in the Bengal tiger, they are so sharp and strong, and the stroke of his paw is so powerful, that they have been known to fracture a man's skull by a touch, in the act of leaping over him.*

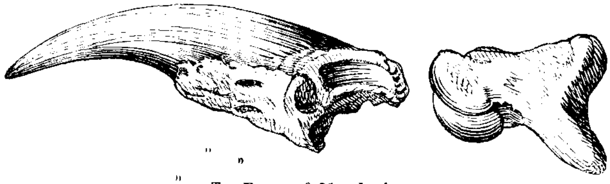


Apparatus of Lion's Claw.

* The pads in the bottom of the lion's foot are soft cushions, which add to its elasticity, and must, in some degree, defend the animal in alighting from his bound. I could not comprehend how the powerful flexor muscles did not unsheath the claws whenever the lion made his spring, and only did so when he was excited to seize and hold the prey; to detect the cause, I made the dissection from which the sketch has been taken. The last bone of the toe, from being drawn back by the elastic ligament (A) beyond the centre of motion of the last joint, is placed in so peculiar a relation to the penultimate bone, that when the animal uses his foot in mere progression, the flexor tendon (B), although inserted into it, only acts in forcing the nearer end, and the cushion of the toe, to the ground. But when the lion strikes his prey to seize it, a more general excitement takes place in the muscles called interossei and extensors (D, E); the relative position of the two last bones is altered; the nearer end of the last bone is withdrawn from beyond the centre of motion of the joint, so that the action of the flexor tendon can now draw it forward or in a line with the penultimate bone,—and then the claw can be unsheathed, and prepared to hold or to tear.

To proceed to the observation of President Jefferson on the Megalonix. *Having found a bone which, by its articulating* surface and general form, he recognised to be one of the finger bones of an animal of great size, he thought he had discovered that it must have carried a claw; and from that circumstance, again, he naturally enough concluded (on the principle—ex ungue leonem) that it belonged to a carnivorous animal. He next set about calculating the length of the supposed carnivorous claw, and from that to estimating the dimensions of the animal; and he satisfied himself that in this bone, a relic of the ancient world, he had obtained proof of the existence, during these olden times, of a lion of the height of the largest ox, and an opponent fit to cope with the mastodon.

But when the same bone came under the scrutiny of Baron Cuvier, his perfect knowledge of anatomy enabled him to draw a different conclusion. He first observed that in the middle of



Toe-Bones of Megalonix.

the articulating surface there was a spine; in that respect it differed from the analogous bone in the feline tribe. He found no provision for the lateral attachment to the next bone; which we have just shown is necessary for the retraction of the claw. Then observing the segment of the circle which the bone described, he prolonged the line, and showed that the supposed claw must have been of such great length, that it could never have been retracted for the protection of its acute and curved point; and it would not have permitted the animal to put its foot to the ground. Pursuing the comparison, he rejected the idea of the bone belonging to an animal of the feline tribe at all. His attention was directed to another order of animals, the sloths, which are characterised by having long nails affixed to their toes. But in the sloth (p. 20) the nails are folded up in a different fashion from the claws of the lion; they just allow

the animal to walk, slowly and awkwardly, as if we were to fold our fingers on the palm of the hand, and bear upon our knuckles. On instituting a more just comparison, therefore, between this bone of the ancient animal and the corresponding bones of the sloth, Cuvier has satisfied us that the supposed enormous lion of the American President was an animal which scratched the ground, and fed on roots.

One experiences something like relief to find that there never existed such a huge carnivorous animal as that denominated megalonix.

These ungual bones, or bones of the claws, exhibit a remarkable correspondence with the habits and general forms of animals. Besides what we have seen in the lion or tiger, in the dog or wolf, in the bear and ant-eater, there is a variety, where we should least expect it, in those animals that live in woods, and climb the branches of trees. The squirrel, having his claws set both ways, runs with equal facility up and down the bole, and nestles in the angles of the branches of trees. The monkey leaps, and swings himself from branch to branch, and in springing, parts from his hold by the hinder extremities, before he reaches another branch with the anterior extremities; he leaps the intervening space, and catches with singular precision. But the sloths do not grasp; their fingers are like hooks, and their strength is in their arms; they do not hold, but hang suspended to the branch; they never let go with one set of hooks, until they have caught with the other; and thus they move along the branch, using both hind and fore feet over head, whilst their bodies are pendant. Here we see, once more, how the form of the extremities, the concentration of strength, and the habits of these animals, correspond not merely to their haunts in the forest, but to their mode of moving and living among the branches; all active, but in different manners.

Of late there have been deposited in our Museum in the College of Surgeons, the bones of an animal of great size; the examination of which affords an opportunity of applying the principles and mode of investigation followed by our great authority in this part of science. These remains consist of part of the head, spine, tail, pelvis; and the bones of one hinder extremity, and the scapula. Estimating the height of the animal to which they belonged at seven feet, it scarcely conveys an

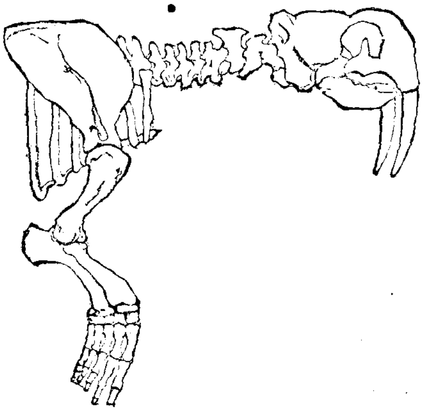
adequate idea of its dimensions; for the thigh-bone is three times the diameter of that of the large elephant, in the same collection, and the pelvis or haunch-bone twice the breadth. If we form our opinion of its configuration on those principles to which we have had repeated occasion to refer, and judge of its strength by the size and prominence of the processes of these bones, we must conclude that the animal possessed extraordinary muscular power; and, directed by the same circumstances, we may obtain an idea of the manner in which that muscular power was employed.

On comparing these bones with drawings of the skeleton of the enormous animal preserved in the Royal Museum of Madrid, we see at once that they are parts of the remains of the great fossil quadruped of Paraguay, the Megatherium of Cuvier. And every observation of the form of the bones of the foot, the scapula, and the teeth, confirms the opinion which he entertained, that it was a vegetable feeder, and that its great strength was employed in flinging up the soil and digging for roots. Corresponding to the provisions in the bones of its feet for sustaining enormous nails or claws, its immense muscular power seems to have been concentrated in its paws. I have heard it surmised that the animal may have sat upon its hinder extremities, and pulled down the branches of trees to itself, to feed upon them. It is only the great weight of its hind quarters that can countenance such an idea. We have not the humerus to declare, by the prominence and situation of its processes, which class of muscles of the arm were the most powerful; but as the scapula has the impression of a clavicle upon its acromion process, that enables us to form some conception of the extent of motion enjoyed by the anterior extremity; and from possessing the greater part of the pelvis, and the enormous bones of the posterior extremity, we can estimate the height, breadth, and strength of the whole animal. In short, judging from the bones that have been procured, we perceive that the muscular power of the Megatherium did not reside so much in the body (certainly not in the jaws) as in the extremities, and especially in the posterior extremities; and that its strength was given neither for rapidity of motion, nor for offence, but for digging.

How little was it to be expected that an alliance between a

part of anatomy so little valued as that of the bones, and mineralogy, should give rise to a new science!—that a department of natural history formerly pursued idly, vaguely, and somewhat fancifully, should henceforth, when thus associated with anatomy, be studied philosophically and inductively! It is both interesting and instructive to find relations thus established between branches of knowledge apparently so remotely connected.

In the true Amphibia, as the phoca (seal) and morse or walrus (sea-horse), the feet are contracted, and almost enveloped in skin, the toes being webbed and converted into fins.* We have sketched here the bones of the paddle of the walrus; and they are remarkably complete, considering the peculiar appearance of the feet in the living animal. The bones are accommodated to form an instrument for swimming; for these animals live in the water; they come to land only to suckle their young, or to bask in the sun; out of the water, they are the most unwieldy and helpless of all animals which breathe.



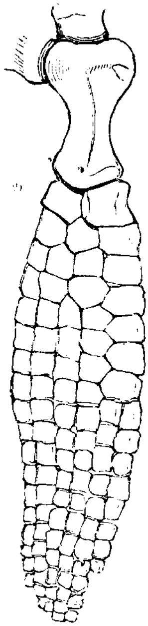
Part of Skeleton of Walrus.

In the Cetacea—for example, the whales and dolphins—we see mammalia unprovided with hind feet. The scapula is large, the humerus very short, and the bones of the fore-arm and hand flattened and confined in membranes, which convert the anterior extremity into a fin. These animals, residing in the water, must rise to the surface to breathe. I need not say that in the dolphin (small bottle-nose whale) we recognise the bones of the anterior extremity, only a little further removed from the forms which we have been hitherto contemplating. The

Bones of Paddle of Dolphin.

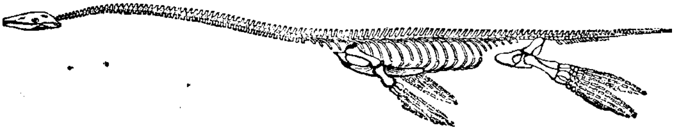
seal and morse raise themselves out of the sea, and bask on the rocks: but the different species of dolphin continue always in the water; the extremity is now a fin or an *oar;* and those who have seen the porpoise, or pelloch, (Scoticè,) in a stormy sea, must acknowledge how complete is the apparatus through which they enjoy their element.

The last examples I select shall be from relics of the ancient world.* These figures are taken from specimens, in the Museum of the College of Surgeons, of fossil animals of singular structure, between the crocodile and fish,—the ichthyosaurus and plesiosaurus. The skeletons are imbedded in a calcareous rock; and are entire, but crushed, and a good deal disfigured. Here are only the extremities, or paddles, consisting of a multitude of bones articulated together: but among these we still recognise the humerus, radius, and ulna, and

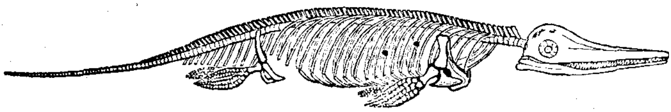


* The figure to the left is the anterior extremity of the Plesiosaurus; to the right, that of the Ichthyosaurus. In these paddles, we see the intermediate changes from the foot of animals to the fin of the fish — modifications of the fins of the walrus, dolphin, or turtle. We no longer discern the phalanges, or attempt to count the bones; they become irregular polygons or trapezoids — less like phalangeal bones than the radii of the fins of a fish. In fishes, the anterior extremity is recognised in the thoracic fin; and we may even discover the prototypes of the scapula and the bones of the arm connected with that fin.

bones of the carpus and fingers. No fault is to be found with the construction of these instruments; the ichthyosaurus and plesiosaurus inhabited seas or estuaries, and the structure of their paddles is suited to their offices; no bone is superfluous, misplaced, or imperfect. It is in the lias deposit that their remains are found most abundantly. Since they existed, great changes have been wrought on the land and in the deep, and in the inhabitants of both; and the races of animals, the structure of whose extremities we have hitherto been engaged in examining, were not then in being. When we discover, therefore, in animals of the old world, that their skeletons* were formed



Plesiosaurus.



Ichthyosaurus.

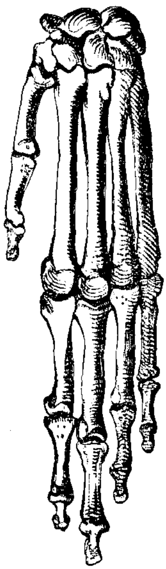
of the same series of bones which compose those of animals now alive, we must admit the existence and the progressive development of a uniform system of bones, extending through a period of time incalculably remote, even if, instead of days and years referable to history, each day were as a thousand years.

I have now given, I hope, a sufficient number of examples of the changes in the bones of the anterior extremity, which suit them to every possible variety of use. After attending a little

* The woodcuts on this page give some idea of the forms of the skeletons of the ichthyosaurus and plesiosaurus, as restored by the Rev. Mr Conybeare.

more to the form of the bones of the human hand, I shall take up another division of my subject.

In this sketch, we have the bones of the paw of the adult Chimpanzee, from Borneo; and the remarkable peculiarity that distinguishes it from the human hand, is the smallness of the thumb; it extends no further than to the root of the fingers. Now, *it is upon the* length, strength, free lateral motion, and perfect mobility of the thumb, that the superiority of the human hand depends. The thumb is called *pollex*, because of its strength; and that strength, being equal to that of all the fingers, is necessary *to the perfection of the hand. Without the* fleshy ball of the thumb, the power of the fingers would avail *nothing; and* accordingly the large ball formed by the muscles of the thumb is the distinguishing character of the human hand, and especially of that of an expert workman.*



Bones of Chimpanzee's Paw.

The loss of the thumb amounts almost to the loss of the hand; and were it to happen in both hands, it would reduce a man to a miserable dependence: or as Adoni-bezek said of the threescore and ten kings, the thumbs of whose hands and of whose feet he had cut off, "they gather their meat under my table." †

In a French book, intended to teach young people philosophy, the pupil asks why the fingers are not of equal length? The form of the question reminds us of the difficulty of putting

* Albinus characterises the thumb as the lesser hand, the assistant of the greater—"*manus parva, majori adjutrix.*" "L'animal superieur est dans la main; l'homme dans la pouce."—*L'Apertigny.*

"The 'great toe' is more peculiarly characteristic of the genus *Homo* than even its homotype, the thumb; for the Monkey has a kind of *pollex* on the hand, but no brute mammal presents that development of the *hallux*, (great toe,) on which the erect posture and gait of man mainly depend."—*Owen on Limbs*, p. 37.—(S.)

† "Poltroon—*pollice truncato*, from the thumb cut off; it being once a practice of cowards to cut off their thumbs, that they might not be compelled to serve in war."—*Johnson's Dictionary.*

them naturally—the fault of books of dialogue. However, the master makes the scholar grasp a ball of ivory, to show him that the points of the fingers are then equal: it would have been better had he closed the fingers upon the palm, and then asked whether or not they corresponded. This difference in the length of the fingers serves a thousand ends, adapting the form of the hand and fingers for different purposes, as for holding a rod, a switch, a sword, a hammer, a pen or pencil, engraving tool, &c., in all which a secure hold and freedom of motion are admirably combined. But we must defer this subject until we have shown the application of the muscles to the bones, and the structure of the ends of the fingers appropriated to bestow feeling.

What says Ray?—"Some animals have horns, some have hoofs, some teeth, some talons, some claws, some spurs and beaks: man hath none of all these, but is weak and feeble, and sent unarmed into the world—Why, a hand, with reason to use it, supplies the use of all these."

Before leaving this part of our subject, let us mark the importance to the science of Geology of these comparative views of anatomy. It has been ingeniously and quaintly said, that the organised remains imbedded in the rocks, are as medals struck in commemoration of those great revolutions which the earth's surface has undergone. Every one must have seen that the crust of the earth is formed in strata or layers: and a very slight consideration leads also to the belief, that this surface, besides having successive deposits or formations laid upon it, has been subject to great convulsions. Each of these layers is, to a certain degree, distinct in the chemical or physical character of its inorganic constituents; but it is chiefly identified by the nature of the animal remains which are buried in it.

Of these strata, some are distinguished by containing the bones of large animals. Now, it is by attending to the forms and processes of such bones, that by far the most interesting conclusions, in the whole range of this new science, are drawn. A very short account of the successive deposits, forming the different strata, will serve to illustrate the importance to the geologist of the anatomy of animals which possess the true bony skeleton. The last grand revolutions have resulted in

forming a surface to the earth, in which strata of every variety of condition have been exposed. And, indeed, we might say that such exposure, by laying open the riches of the earth to our reach, as well as furnishing mixed soils for vegetation, has been the end of these convulsions. At all events, the variety of objects disclosed on the surface excites the interest of the inquirer. We will, therefore, recapitulate briefly what has been discovered by the investigations of scientific and ingenious men in our time.

Without hazarding conjectures on the elevation or production of the "primitive rocks," we have at present only to notice the stratifications superimposed. Of these, the most striking, and the most difficult to reconcile to theory, are the strata of coal: but we pass over them as containing no animal remains in which the knowledge of the anatomy of the vertebrata can be of use. Knowing that these beds of coal are vegetable productions, we might expect to find the remains of terrestrial animals within them: but it is conjectured that the land, where the trees of that period grew, did not form a suitable habitation for animals corresponding to those of the present epoch. Above the beds of coal are the strata, regular and well ascertained, which are chiefly interesting as indicating the presence of the coal beneath. The next remarkable stratifications come to be connected with our subject; because they contain the remains of gigantic animals, with a regular skeleton, on the system of the vertebrata.*

Some of the great reptiles here alluded to are estimated to have been eighty feet in length.† But although their skeletons were formed on the plan, if we may so express it, of quadru-

* Since the above was written, remains *of fishes, the lowest order of vertebrata, have been found in the* Silurian beds, below the coal: and both fishes and reptiles, although but a few of the latter, in the coal itself. It remains true that reptiles, the next above fishes, are most abundant in the secondary strata, referred *to in the text.*—(S.)

† The Megalosaurus, discovered by Professor Buckland in Oxfordshire, is supposed to have been about seventy feet in length. The Iguanodon, an herbivorous masticating reptile, first discovered by Mr Mantell *in the Wealden beds, in* Sussex, *is computed* to have been seventy or eighty feet in its entire length, its tail being fifty feet, its height nine feet, its hind foot six feet and a half, and its body about the same thickness as the elephant's. The Hylæosaurus, the last discovered of these *huge animals in the same* beds, and supposed by Mr Mantell to have been a reptile intermediate between the crocodiles and the lizards, is estimated to have been about thirty feet in length. See the Appendix.

peds, the extremities in many were more like paddles than feet: and we conclude that they were capable of dragging their huge bulk on the land, only because their structure proves them to have been oviparous, and to have breathed the atmosphere. Some had a conformation of extremities resembling that of recent oviparous quadrupeds, for enabling them to walk or crawl on slimy ground; and judging by the habits of these, as of the crocodile, gavial, alligator, and cayman, certain species of which existed among them, it is probable that they lived in still water, with muddy bottom, retreating under the mud, and projecting their snouts between the aquatic plants to breathe. And they must have been prolific to an extraordinary degree, as they had not for enemies the vulture and the ichneumon, which destroy multitudes of the eggs of these creatures of the present day. Others had the skin extended on their anterior extremities,* if not to provide a power of flight, at least to allow them to drop in safety from elevations to which they might have crept.

The stratified rocks which contain remains of these reptiles are composed of lime, clay, or sandstone, and are known under the denominations of lias, oolite, Wealden or Sussex beds, Stones-field slate, &c. They are visible in the south of England, and extend to many parts of Europe. There is every appearance of these deposits having been submerged and deeply buried in the ocean, from which thick beds of chalk have been deposited over them. Above the chalk, again, is to be found a series of stratified rocks, implying a new condition.

The lowest layer of this "tertiary formation" situated above the chalk, is sometimes called the deposit of the Palæotherian period. In this division, animals of a distinct creation, the species of which cannot be identified with those imbedded in the strata under the chalk, are found. Then, for the first time, was there a condition of the earth suited for terrestrial animals, which retire under the shade of woods and give suck,—the mammalia. Yet it is remarkable, that the animals of the class mammalia in this lowest stratification of the tertiary formation, only approached in resemblance to those which are now alive: we find the remains of such only as are now extinct.

When the layers forming the tertiary beds are examined in

* The Pterodactyles, see page 53.

succession upwards, they are still distinguishable by their organic products: and as we approach the most recent beds, there are fewer remains of extinct quadrupeds, and more numerous specimens of such as now inhabit the earth. We find, in the different strata, the bones of the mammoth, the megatherium, the elephant, the tapir, the rhinoceros, the hippopotamus, the stag, the ox, the horse, and with them the skeletons of their natural enemies of the feline tribe, and the bear and the hyæna, the bones of some of which prove them to have been of greater strength and size than those now alive.*

Over the earth's surface, there are evidences that deluges have swept with inconceivable power, brushing off the superficial strata, rolling immense rocks, and depositing the debris, so as to fill chasms, form new accumulations, and with successive elevations and subsidences, to change the whole character of the earth's surface. It was then that the globe assumed its present confines of land and sea, and that the valleys and the courses of rivers were determined. Out of these convulsions and revolutions has come that condition of the world which we now enjoy; and, as I shall have occasion to repeat, no previous state of the earth would have been suitable to our constitution.†

My admiration of the labours of our geologists partakes of a feeling of gratitude. But yet there is something in the subject which leads the devoted student to be over ambitious, and to frame theories almost too comprehensive. It is not enough to say that, after all, the changes on the earth's surface are not greater, in comparison with the size of the earth, than the cracks in the varnish are to the globe that stands on the table. It has been

* See Sir C. Lyell's works, for his Classification of the Tertiary Formations.

† When doctrines or principles are laid down dogmatically, there is an end of reasoning; "they are as fetters on the feet, and like manacles on the right hand." In this way, the most famous schools have sunk; for if it become a crime to doubt or investigate, the mind decays. When God informed us of our duties to Himself and to each other, the exercise of our affections was enjoined and left free. To have taught mankind the nature of physical things, would have made it the duty of the pious to seek no further knowledge, and researches into them would have implied presumption. But by the constitution of the mind, we learn that had we been left in a state of passive obedience, without object or impulse, the loss of the affections as well as of reason would have followed; our sense of goodness and benevolence would have become obtuse, and the charities of life and the love and duty we owe to God must have decayed in us.

Why, then, do geologists quote Scripture, and form their opinions

part of our object to show that the features of our earth, and the phenomena around us, are suited and intended to excite the faculties and imagination. Accordingly, when the geologist, extending his survey from the mountains, over extensive plains, and into ravines and valleys, persuades himself that he can explain when and how they have been formed, he is tempted to indulge in an enthusiasm which can only be permitted to the poet.

Wonderful improvements have, indeed, been made in this science by our countrymen who have associated themselves for that purpose. Buckland, Conybeare, and Mantell, are especially distinguished for the discovery of those large Saurian reptiles; whilst other geologists have exerted their genius and industry with equal effect in different departments. But it is in contemplating the labours of Cuvier, that we have the earliest and best proofs of the importance of comparative anatomy, in giving extraordinary interest to geology. In him was combined an attention to minute objects, with a power of generalising, highly characteristic of genius. Years had been passed in accumulating fossil specimens from the tertiary beds round Paris; and out of these heaps of animal remains, which lay confused as if the fragments of bone had been washed to his feet by a torrent, he was enabled, by following the principle which the early part of this chapter has shown to prevail—the co-relation of the parts of the skeleton—to put together the separate members, to build up the bodies of extinct animals anew, and to present them to us with a precision which we could only have expected from the dissection of the recent animals.

of the structure of the earth on the Mosaic account of the Creation? It does not require deep theological knowledge to comprehend what was intended by that sublime announcement. It was addressed to a people ever prone to fall into the idolatries of surrounding nations. In teaching the Creation of the world, it affirmed the existence of One God pre-existing and eternal. It denied the existence of gods and demons sprung from the earth: it denied that the Deluge was one of a necessary succession of events: or that the earth was subject to be successively destroyed or restored: or that those who flourished to the advantage of mankind in one period, should be restored to a similar existence in another. It taught the just relations of the heavenly bodies to the earth, and that they were not the abodes of deified mortals—for these were opinions maintained by the surrounding nations. Surely, then, men are inconsistent, when they expect to find in the Scriptures, which teach the unalterable religious and moral duties, the principles of an uncertain science.

The phenomena visible in the heavens, on the earth, and within it, are of a nature, taken by themselves, to overwhelm the inquirer's mind. To learn his own value, man must consider himself, his physical endowments and capacities, and compare them with the elements around. Without a true conception of his position and relations, the whole range of natural science is barren of consolation; the periods of the revolution are too vast, the objects too distant, to seem to have as their prospective design the condition of the human race.

"God made the country;" and it is perhaps in surveying plains, and meads, and mountains, remote from man, that the mind is most elevated to pure and high contemplations. But cities, temples, and the memorials of past ages, bridges, aqueducts, statues, pictures, and all the elegancies and comforts of the town, are equally the work of God, through the propensities of His creatures, and, we must presume, for the fulfilment of His design. The condition of the earth has by successive revolutions been made to conform to these works of man, and afford the means for them. The metallic veins of the primitive rocks have been exposed; the carboniferous strata, the lime and freestone, have been disjointed and elevated; the riches of the interior of the earth as well as of its prolific surface, the circulation of water and the formation of springs—all give proof that it was designed that the earth should be subdued to man's use; that he should not live a selfish, solitary, nomad life, but in society, where his higher faculties should be called into activity and his social virtues exercised.

CHAPTER IV.

OF THE MUSCLES OF THE ARM AND HAND—THEIR VITAL ACTION — THEIR MECHANICAL ADAPTATION TO THE MOTIONS OF THE HAND AND FINGERS — FORM OF THE HUMAN HAND.

THE Muscle of the body is that fleshy part with which every one is familiar. It consists of fibres which lie parallel to each other. This fibrous structure has a living endowment, a power of contraction and relaxation, termed irritability. A single muscle is formed of some millions of these fibres combined together, having the same point of attachment or origin, and concentrating in a rope or tendon, which is fixed to a moveable part, called its insertion. Upwards of fifty muscles of the arm and hand may be demonstrated, which must all consent to the simplest action. Yet that gives but an imperfect view of the extent of the relation of parts necessary to every act of volition. We are the most sensible of this combination in the muscles when inflammation has seized any great joint of the body; for then, even in bed, every motion of an extremity gives pain, owing to a corresponding simultaneous movement in the trunk. When we stand, we cannot raise or extend the arm without a new poising of the body, through the action of a hundred muscles.

ON THE ACTION OF THE MUSCLES OF THE ARM.

We shall consider this subject under two heads; first, we shall give examples of the living property of muscles; then, of the mechanical contrivances, in their form and application.

First, In all that regards the living endowment of the muscles, we see the most bountiful supply of power commensurate to the object, but never anything in the least degree superabundant. If the limb is to be moved by bringing a muscle or a set of muscles into action, the power is not bestowed in that excess which would enable them to overcome their opponents; but the property of action is for the time withdrawn from the

opponents; they become relaxed, and the muscles, which are in a state of contraction, perform their office with comparative ease. A stationary condition of the limb results from a balanced but regulated action of all the muscles; which condition may be called their tone. If, in an experiment, a weight be attached to the tendon of an extensor muscle, it will draw out that muscle to a certain degree, until its tone or permanent state resists the weight: but if the flexor muscle be now excited, this being the natural antagonist of the extensor, the weight will fall, by the relaxation of the extensor. So that the motion of a limb implies a change in both classes of muscles, the one set contracting, the other relaxing; and the will influences both classes. Were it not so regulated, instead of the natural, easy, and elegant motions of the frame, the attempt at action would exhibit the body convulsed, or, as the physicians term it, in clonic spasms. The similitude of the two sawyers, adopted by Paley, gives but an imperfect idea of the adjustment of the two classes of muscles. When two men are sawing a log of wood, they pull alternately; when the one is pulling, the other resigns all exertion. But this is not the condition of the muscles—the relaxing muscle does not give up all effort, so as to be like a loose rope, but it is controlled in its yielding, with as fine a sense of adjustment as is the action of the contracting muscle. Nothing appears more simple than raising the arm, or pointing with the finger; yet in that single motion, not only are innumerable muscles put into activity, and as many thrown out of action, but both the relaxing and the contracting muscles are controlled or adjusted with the utmost precision, though in opposite states, and under one act of volition.

By such considerations, we are prepared to admire the faculty which shall combine a hundred muscles so as to produce a change of posture or action of the body. We now perceive that the power taken from one class of muscles, may be considered as bestowed on the other; so that the property of life, which we call the irritability, or action of a muscle, is upon the whole less exhausted than would be the case on any other supposition.

As to the second head;—Our demonstration is of an easier kind. We have said that nature bestows abundantly, but not superfluously; a truth evinced in the arrangement of the muscles. In all the muscles of the limbs, the fibres run in an oblique

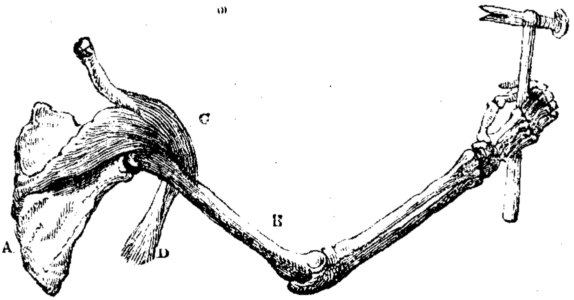
direction,—thus, A being the tendinous origin of a muscle, and B the tendinous insertion, the fleshy fibres C run obliquely between these two tendons. The fibre acting thus obliquely loses power, but gains the property of pull-

ing what is attached to its further extremity through a greater space, while it contracts; and consequently the velocity is increased. This mechanical arrangement is intelligible on the law, that velocity of motion through space is equal to power and weight. Here, there is a resignation of power in the muscle to gain velocity of motion. The same effect is produced by the manner in which the tendons run over the joints. If they went in a straight line to the toes or tips of the fingers, the muscles would act more powerfully; but the tendons being braced down in sheaths, they move the toes and fingers with a velocity increased in proportion to their loss of power.

Let us see how far this corresponds with other mechanical contrivances. A certain power of wind, water, or steam being obtained, the machinery is put in motion; but it is desired to give a blow, with a velocity far greater than the motion of the water or the turning of the wheels. For that purpose a fly-wheel is put on, the spokes of which may be considered as long levers. The wheel moves very slowly at first; but being once in motion, each impulse accelerates it with more and more facility; at length, it acquires a rapidity, and a centrifugal force, which nothing but the explosion of gunpowder can equal in its effects. The engineer, not having calculated the power of accelerated motion in a heavy wheel, has seen his machinery split and burst up, and the walls of the house blown out, as by the bursting of a bombshell. Or, a body at rest receives an impulse from another, which puts it into motion—it receives a second blow; now, this second blow has much greater effect than the first—for the power of the first was exhausted in changing the body from a state of rest to that of motion—but being in motion when it receives the second blow, the whole power is bestowed on the acceleration of its motion; and so on, by the third and fourth blows, until the body moves with a velocity equal to that of the body from which the impulse is originally

given. The slight blow given to a boy's hoop is sufficient to keep it running; and just so the fly-wheel of a machine is kept in rapid action by a succession of impulses, each of which would hardly put it in motion. If we attempt to stop the wheel, it will inflict a blow in which a hundred lesser impulses are combined and multiplied.

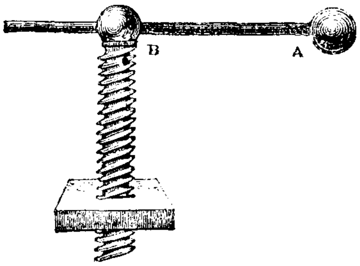
In the machinery of the animal body, there is, in a lesser degree, the same interchange of weight with velocity and force.



When a man strikes with a hammer,* the muscle C, near the shoulder, acts upon the humerus, B, in raising the extended lever of the arm and hammer, with every possible disadvantage, seeing that it is inserted near the centre of motion in the shoulder-joint; and the same remark applies to the muscle D. But the loss of power is restored in another form. What the muscle D loses by the mode of its insertion, is made up in the velocity communicated to the hammer; for in descending through a large space, it accumulates *velocity*, and *velocity* and weight are equal to force. The advantage of the rapid descent of a heavy body is, that a smart blow is given, and an effect produced which the combined power of all the muscles, without this mechanical distribution of force, could not accomplish. It is, in truth, similar to the operation of the fly-wheel, by which the gradual motion of

* A, the scapula, or shoulder-blade; B, the humerus, or arm-bone; C, the deltoid muscle of the shoulder, arising from the shoulder-blade and clavicle, and inserted into the arm-bone; D, a muscle which draws the arm down, as in striking with a sword or hammer.

an engine is accumulated in a point of time, and a blow struck capable of stamping a piece of gold or silver. In what respect does the mechanism of the arm differ from the engine with which the printer throws off his sheet? Here is a lever with a heavy ball at the end; in proportion to its weight it is difficult to be put in motion; the printer, therefore, takes hold of the lever near the ball, at A; were he to continue pulling at that part of the lever, he would give to the ball no more velocity than that of his hand; but having put the ball into motion, he slips his hand down the lever to B. Had he applied his hand near B at first, he could not have moved the weight; but the ball being now in motion, if



he direct the whole strength of his arm to the lever near the centre of motion, the velocity of the weight at the further end will be greatly accelerated. Thus the weight and velocity being combined, the impulse given to the screw is much more powerful than if he had continued to pull upon the further end of the lever at A.

If we now turn back to the diagram (page 84), we shall understand how much is gained by the muscle C being inserted near the centre of motion, although, in one sense, at a mechanical disadvantage. First, that mode of insertion is in correspondence with the principle already adverted to, that the living endowment of muscle is never spared, but is bestowed liberally in proportion to the necessities of the part. But it will also be perceived, that the arm being put in motion by the force operating near the centre of motion, the velocity will be rapidly increased by each successive impulse from the muscle; and, of course, the motion at the further extremity will be more rapid than at the insertion of the muscle. Again, in the action of pulling down the arm, as in giving a back stroke with the sword, we perceive that when the hammer descends, the rapidity is increased by the mere effect of gravity; but when the action

of the muscle is conjoined, the two forces, progressively increasing, greatly augment the velocity of the descent.

The same interchange of power for velocity, which takes place in the arm, adapts a man's hand and fingers to a thousand arts, requiring quick or lively motions. The fingers of a lady playing on the pianoforte, or of the compositor with his types, are instances of the advantage gained by this sacrifice of force for velocity of movement. The spring of the foot and toe is bestowed in the same manner, and gives elasticity and rapidity in running, dancing, and leaping.

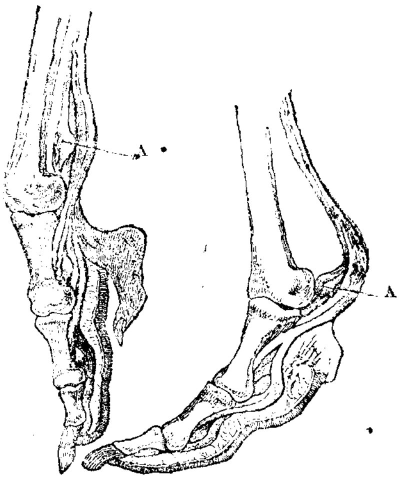
The motions of the fingers do not result merely from the action of the large muscles which lie on the fore-arm: these are for the more powerful efforts; in the palm of the hand, and between the metacarpal bones, are numerous small muscles, (*lumbricales* and *interossei*,) which perform the finer movements, —expanding the fingers, and moving them in every direction with quickness and delicacy. These small muscles, attached to the extremities of the bones of the fingers where they form the first joint, being inserted near the centre of motion, move the ends of the fingers with great velocity. They are the organs which give the hand the power of spinning, weaving, engraving, &c.; and as they produce the quick motions of the musician's fingers, they are called by anatomists *fidicinales*.

But there is another use which the small muscles in the hand serve. In grasping with the hand, the strength with which it closes, when all the muscles are combined in action, must be very great; the amount of power is exhibited when we see a sailor hanging by a rope, and raising his whole body with one arm. What must be the pressure upon the hand? If the palms, and inside of the fingers, and their tips, were not guarded by cushions beneath the skin, it would be too much for the texture even of bones and tendons, and certainly for the blood-vessels and nerves, to sustain. The elastic pad in the foot of the horse, camel, or ostrich, is not a whit more appropriate than the fine elastic texture beneath the skin of the hand. To add to the efficacy of this yielding but strong padding, a muscle is provided, which, arising in the centre, runs across half the palm to the cushion, on the inner edge, opposed to the ball of the thumb: it acts powerfully as we grasp; and it is this muscle which, by

raising the edge of the palm, hollows it, and adapts it to lave water, forming the cup of Diogenes.

Whilst the cushions on the ends of the fingers protect them in the powerful actions of the hand, we shall presently see that they are useful also in subservience to the organ of touch; that they provide a power of receiving impressions, without which the utmost delicacy of the nerves would be unavailing.

The projection of the heel in the human foot, and the prominence of the knee-pan, are provisions for increasing, by mechanical adjustment, the power of the muscles. By such means the point of insertion of the muscle is removed to a distance from the centre of motion in the joint, and the lever power thus obtained is added to the force of the muscle. The principle is maintained, and the demonstration more easy, in the joints of some animals, as in the hock of the horse; and we have a beautiful instance of it in the foot of the ostrich. Where the flexor tendons pass behind the several joints of the foot, the heads of the bones are enlarged; which throws the tendons off from the centre of motion. But there is an additional provision still. A loose pendulous body, A, hangs between the tendons and bone, at each of these joints; and it plays upon the bones in such a manner, that at the utmost degree of extension of the foot, when the bird requires to use all its power of muscular exertion to bend it again, this body is introduced to throw the tendons further backwards, and to add remarkably to the lever power. This body, A, is shaped like a wedge, with grooved surfaces to cor-



Ostrich's Foot.

respond with the bone before, and the tendon behind: and it is suspended by an appropriate muscle, which raises it like a bolt, after it has served the office of throwing off the tendons from the centre of motion. In addition, the sketch shows, that where these tendons pass behind the joints, they are thickened and hardened into cartilages, so that the bolt operates more effectually in directing them backwards, and producing the projection, equivalent to that of the heel or the hock.* These are the means by which "she lifteth up herself on high, and scorneth the horse and his rider."

After the many illustrations which we have adduced from mechanics, the muscular power itself must be a subject of surprise and admiration. Gravity, the expansion and condensation of steam, the evolution of gases, the spring or elasticity of material, or all these combined, could not have answered the various offices performed by this one property of life—muscular contractility. The irritable and contractile fibre, of which muscle is composed, when chemically considered, does not differ from the fibrine of the blood; but from being endowed with this property of contraction, and adapted with "mechanical ingenuity," it fulfils a thousand distinct purposes, in volition, breathing, speaking, digestion, circulation; and it is modified in all these functions according to the wants and condition of every class of animals.

From what the reader already understands of the conformity subsisting among all parts of an animal body, he will readily comprehend that a perfect relation must be established between the bones and the muscles: that as the bones of different animals exhibit a variety in their size, relative position, and articulations, so must there be an adaptation of the muscles. Accordingly, we sometimes find the muscles separated into smaller, and sometimes consolidated into more powerful masses. To the anatomical student, the mode of demonstrating the muscles of the human hand and arm becomes the test of his master's perfection as a teacher. When they are taken successively, just as they present themselves in the arm, nothing can be more uninteresting, tedious, and difficult to attend to, than such a demonstration; but when they are taught with lucid

* I am indebted to Mr Shaw for these interesting demonstrations of the ostrich's foot.

arrangement, according to the motions performed by the distinct groups of muscles, it is positively agreeable to find how much interest may be communicated to the subject.

It would be foreign to the object of this work to introduce such demonstrations here. Yet it is remarkable how closely the muscles of the arm and hand resemble the muscles of the fore extremity of certain animals—the lion, for example. The flexors, extensors, pronators, and supinators, in the brute, are exactly in the same relative place which the student of anatomy is taught to observe with so much interest in the human arm. This example shows how accurately the arrangement of the muscles conforms to the structure of the bones; and that in proportion as the bones of the extremity of any animal resemble, in shape and power of motion, those of the human arm, so will the muscles—another proof of the extent of the system of analogies established in the animal frame.

There is one circumstance more which should not be omitted in the comparative anatomy of these muscles, as it exhibits another instance of conformity in the structure of parts, to the offices they have to perform. We have just stated that the power of contraction is a vital property. The continued action of a muscle, therefore, exhausts its vitality. Now, to support that action, when inordinate, there must be a more than usual provision for the supply of the living power to the muscle—there must be a means of increasing or maintaining the circulation of the blood within it, that being the source of all vital power.

In the *loris tardigradus** it has been observed that the axillary and femoral arteries, the great arteries of the anterior and posterior extremities, present this peculiarity—the main vessel is subdivided into a number of equal-sized and tortuous cylinders, which, previous to the distribution of the proper branches to the muscles, again unite to form a single trunk.† As this subdivision of the trunk of the vessel produces a retardation of the blood, it has been argued that it is adapted to the slow motion of the animal. On the contrary, I believe it to be a provision for long-continued action. The animals which possess this peculiarity in their circulation are not more remark-

* See p. 21.

† There is some doubt as to the reunion of the vessels.

able for the slowness of their progression than for the tenacity of their hold; their extremities are long and their muscles powerful, either for sustaining the animal by grasping the branches of trees, or for digging. But surely the strength of the muscles cannot be maintained by retarding the circulation of the blood: it is a principle universally admitted, that the expenditure of arterial blood always bears a proportion to the vital force employed.

Buffon tried to make a dog amphibious, by immersing the puppy, before it had breathed, in tepid water. One of our own physiologists thought it possible, by putting ligatures upon the arteries which go to the limbs, and forcing the blood to take a circuitous course, and by numerous channels, to the muscles, to make a tardigrade animal, like the loris, out of a vivacious spaniel. We need hardly say that these experiments failed. They were undertaken in a misconception of the nature of the living properties of muscles, which are more finely adjusted than anything in the mere mechanism of the body. Every muscle has its prescribed mode of action, from the unwearied irritability causing the incessant motion of the heart, to the simple effort of the muscle which guides the pen. Some muscles are ever in action, with but short intervals of rest; others act in regular succession: some are under the will, others withdrawn from it: some act quickly, as the heart; others slowly, as the stomach: but these are original endowments, and do not result from the force or languor of the circulation of the part.

To return to the subdivided and tortuous artery—were the blood-vessels of the living body like rigid tubes, and the laws of the circulation the same as those of hydraulics, such a form of the artery would certainly be the means of retarding the course of the blood. But it is impossible to believe that the circulation of the blood can be performed according to the same laws which govern the flow of water in dead tubes. The artery is dilatable; it contracts with a vital force; and both the dilatability and the contractility of arteries are subject to the influence of the living principle. When, therefore, the artery of a limb is divided into four or five vessels, which are tortuous, as in the sloth, the result will be a greater capacity of dilatation, and a greater power of contraction; and these, being vital

operations, will be subject to be influenced and adjusted according to the necessity for the increase or diminution of the circulation. If such a peculiarity in the form of the vessels in the extremities of these animals retard the blood, it can only be during repose; for, on excitement, so far from retarding, it must bestow a remarkable power of acceleration. I conclude, therefore, that this variety of distribution in the arteries is a provision for an occasional increase of activity in the muscles of the limb, and for forcing the blood into contact with the fibres, notwithstanding their long-continued action and rigidity. We have seen, in the preceding chapter, that the same animal which at one time moves out its paw as slowly as the hand of a watch, at another, when seizing its prey, acts with extreme rapidity: consequently, we cannot admit the inference that the tortuous and subdivided artery is a provision for languid movements.

OF THE RIGHT AND LEFT HAND.

In speaking of the arteries which go to the hand, it may be expected that we should touch on a subject, formerly a good deal discussed, *whether the properties of the right hand, compared with the left, depend on the course of the arteries*: for it has been affirmed that the superiority of the right arm is owing to the trunk of the artery which supplies it, passing off from the heart more directly, so as to admit of the blood being propelled more forcibly into the small vessels of that arm, than the left. This, however, is assigning a cause altogether unequal to the effect, and presenting too confined a view of the subject: it partakes of the common error of seeking in the mechanism, the explanation of phenomena which have a deeper origin.

Among all nations, there is a universal consent to give the preference to the right hand over the left. It cannot, therefore, be a conventional agreement: it must have a natural source. For the conveniences of life, and to make us prompt and dexterous, it is pretty evident that there ought to be no hesitation which hand should be used, or which foot should be put forward; nor is there, in fact, any such indecision. Is this readiness taught, or is it given to us by nature?

Sir Thomas Browne says, that if the right side were originally

the most powerful in man, we might expect to find it the same in other animals. He affirms that squirrels, monkeys, and parrots feed themselves with the left leg rather than with the right. But the parrot may be said to use the strongest foot where most strength is required; that is in grasping the perch and standing, not in feeding itself.

That the preference for the right hand is not the result of education, we may learn from those who by constitution have a superiority in the left. They find a difficulty in accommodating themselves to the modes of society: and although not only the precepts of parents, but every thing they see and handle, conduce to make them choose the right hand, yet will they rather use the left.

It must be observed, at the same time, that there is a distinction in the whole right side of the body, as well as in the arm: and that the left side is not only the weaker, in regard to muscular strength, but in its vital or constitutional properties. The development of the organs of motion is greatest upon the right side; as may at any time be ascertained by measurement, or the testimony of the tailor or shoemaker. Certainly, the superiority may be said to result from the more frequent exertion of this side; but the peculiarity extends to the constitution also; and disease attacks the left extremities more frequently than the right. We see that opera dancers execute their more difficult feats on the right foot: but their preparatory exercises better evince the natural weakness of the left limb; in order to avoid awkwardness in the public exhibitions, they are obliged to give double practice to the left leg; and if they neglect to do so, an ungraceful preference to the right side will be remarked. In walking behind a person, we seldom see an equalised motion of the body; the tread is not so firm upon the left foot, the toe is not so much turned out, and a greater push is made with the right. From the peculiar form of woman, and from the elasticity of her step, resulting from the motion of the ankle rather than of the haunches, the defect of the left foot, when it exists, is more apparent in her gait. No boy hops upon his left foot, unless he be left-handed. The horseman puts the left foot in the stirrup and springs from the right. We think, therefore, we may conclude, that the adaptation of the form of everything in the conveniences of life, to the right hand—as for example,

the direction of the worm of the screw, or of the cutting end of the auger, or the shape of other tools or instruments—is not arbitrary, but has relation to a natural endowment of the body. He who is left-handed is most sensible to the advantages of this arrangements, whether in opening the parlour-door, or a penknife. On the whole, the preference of the right hand is not the effect of habit, but is a natural provision, and is bestowed for a very obvious purpose: and the property does not depend on the peculiar distribution of the arteries of the arm—the preference is given to the right foot, as well as to the right hand.*

* There is a pleasant and ingenious epistle by Dr Franklin, in which the left hand is personated, and made to contend for equal rights. She complains of being suffered to grow up without instruction—that she has had no master to teach her writing, drawing, and suitable accomplishments: that, on the contrary, she is left totally without exercise, but for the sympathy of her sister. To the countrymen of Dr Franklin the lesson of the subordination of the organs of the animal frame is not altogether unsuited.

CHAPTER V.

THE SUBSTITUTION OF OTHER ORGANS FOR THE HAND.

After having examined how one instrument, the hand, is modified and adapted to a variety of uses in different animals, it only remains, for elucidating the subject further, to contrast the hand with its imperfect substitutes in other creatures. From the insect tribe, I might have derived some of the most curious examples of instruments suited for purposes similar to those of the hand and fingers of man; but I have intentionally confined the inquiry to the higher classes of animals.

The habits of certain fishes require that they should cling firmly to the rocks, or to whatever is presented to them as a means of support. Their locomotive powers are perfect; but how do they become stationary in the tide or stream? For example, I have often thought it wonderful that the salmon or trout should keep its place, night and day, in the rapid current.

[The poising and motion of fishes in the water has interested some of our greatest philosophers, as Galileo and Borelli. It is estimated that fishes make their way through a medium which resists nine hundred times more than the atmosphere: but then, as it offers a certain resistance to their progress, it resists also the motion of their tail and fins by which they have their power of progression. The breadth of the tail of fishes, compared with that of their fins, and its muscularity and power, declare what is affirmed to us upon authority—that the tail is the great instrument of their progression; and we can see that when the trout darts away, the force of his motion lays down the fins close upon his body. But the fins direct him, as out-riggers, and the pectoral fins especially, by raising or depressing the head, give direction to the whole body under the force of the tail. The lateral fins, and particularly the pectoral fins, also sustain him in the right position in the water: without the co-

operation of these with the tail, the fish would move like a boat sculled by one oar at the stern. As the digestion of fishes, as well as that of other animals, is attended with the extrication of air, and as the intestines are below the centre, the belly would be turned up but for the action of these lateral fins ; as we see takes place in a dead fish. The tail and fins are the instruments of motion; but the incessant action of the muscles which move these is a just matter of admiration. If a fish move with his head down the stream, he must move more rapidly than the water, or the water gets under the operculum of the gills, and chokes him. He lies, therefore, continually with his head to the stream. We may see a trout lying for hours stationary, whilst the stream is running past him ; and they seem to remain so for days and nights. In salmon-fishing, the fly is played upon the broken water, in the midst of the torrent; and there the fish shows himself rising from a part of the river where men could not preserve their footing, though assisted by poles, or by locking their arms together. When the salmon leaps, he makes extraordinary exertions. Just under the cataract, and against the stream, he will rush for some yards, and rise out of the spray six or eight feet; and amidst the noise of the water, they may be heard striking against the rock with a sound like the clapping of the hands. If they find a temporary lodgment on the shelving rock, they lie quivering and preparing for another somerset, until they reach the top of the cataract. This exhibits not only the power of their muscles, assisted by the elasticity of their bones, but the force of instinct by which they are led to seek the shallow streams for depositing their eggs. The porpoise will sail round and round a ship which is sailing at fourteen miles an hour: a thing almost as surprising as the fly circling round the horse's ear for a whole stage. To all this may be added, that the solid which mathematicians have discovered, by refined application of the calculus, and have termed "the solid of least resistance," because it is the conformation which is less than any other affected by the resistance of any medium, resembles a fish in its form.* The sea varies in temperature and pressure at different depths, and no doubt the texture of the fish, and especially of its integument, must conform

* According to Lacepede, the speed of a salmon is about twenty-six feet in a second.

to this variety. The swimming-bladder is the means of adjustment by which the fish lives at its native depths without waste of animal exertion: such is the power of expansion of the air-bladder when relieved from the pressure, that, when a fish is brought up from the greatest depth, it inverts and thrusts out the viscera from the mouth. We do not see, however, that naturalists have adverted to the place of this swimming-bladder. It lies close to the spine, and appears to counterbalance, in some measure at least, the air in the intestines by being thus placed above them. In the Cetacea, as the whale, their buoyancy proceeds from the quantity of oil under the skin, especially of their head, and which it has been observed is bestowed in order to insure their readily coming to the surface to breathe when their natural powers are weakened. For the same reason, that they may raise their heads to the surface, their tails are horizontal. In the jelly-fish, those soft animals which float in sheltered estuaries (the *physsophora*), there is an air-vessel which they can fill and empty, by which means they rise or sink at pleasure. Others (the *villela*) raise a sail. Some of this class propel themselves by taking in water, and suddenly rejecting it.]*

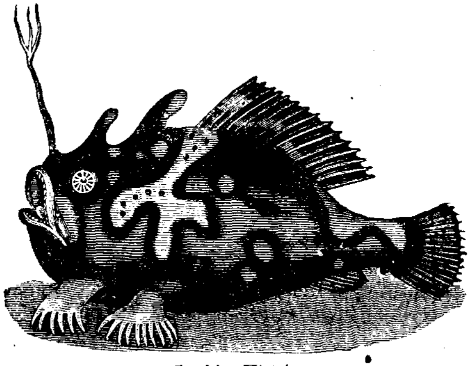
In the sea, some fishes are provided with special means of clinging to the rocks. The lump-fish (*cyclopterus lumpus*) fastens itself by an apparatus on the lower part of its body; while the sucking-fish (*remora*) has a similar provision on its back, by which it attaches itself to the shark, or to whatever is afloat, as the bottoms of ships: and it was from the ancients believing that this fish was able to stop a ship under sail, that Pliny called it remora. We must admire the means by which these fishes can retain their proper position in the water, without having to cling either by their fins or their teeth, or being prevented from catching their food. The apparatus resembles a boy's sucker: the organ is pressed against the surface to which the creature is about to fix itself, the centre is then drawn upon by muscles, in the same manner as the sucker is drawn by the cord, and thus a vacuum is made. Dr Shaw tells us, that on throwing a lump-fish into a pail of water, it fixed itself so firmly to the bottom, that when he took hold of it by

* Author's note, in edition of "Paley's Natural Theology, with illustrative notes by Lord Brougham and Sir Charles Bell."

the tail, he could lift the pail off the ground, although it contained some gallons of water.*

In the cuttle-fish we see a modification of the same kind of apparatus : the suckers are ranged in rows along the lower part of their feelers or arms, so as to become instruments of prehension and of locomotion. They can be turned by the animal in any direction, either to fix itself, or to drag itself from place to place. In the Indian seas these creatures become truly formidable, both from the length of their arms, which extend to eight or nine feet, and from the tenacity with which they cling.†

There is another fish, which, from its name, we should expect to be able to perform strange antics; it is called the "harlequin angler."‡ The appearance of the fish is grotesque and singular;



Lophius Histrio.

* For a description, by Macgillivray, of a mode of capturing turtles, by attaching a cord to sucking-fishes trained for the sport, see "Account of the Surveying Voyage of the *Rattlesnake*."

† In the Mollusca and Zoophytes, we find many instances of animals holding on against the force of tide or current. The Actiniæ fix themselves to rocks and shells; and some, as the sea-carnation, hang suspended from the lower surface of projecting rocks, resembling the calyx of a flower. By the elongation of their tentacula, they expand and blow themselves out; the parts like petals being prehensile instruments, by which the animal draws whatever food floats near it, into its stomach. The byssus of the mussel is a set of filaments secreted from a gland near the joint; being fixed to the rock at one end, it retains the shell at anchor, preventing it from drifting or rolling with the tide. In the oyster, the shell is directly cemented to the rock.

‡ *Lophius Histrio*,—the first word, from the Greek, denotes the feeler which flies at the head like a pennant; the second, from the Latin, signifies an actor.

the pectoral fins resemble short arms, and are palmated at their tips.* M. Renau, in his History of Fishes, affirms that he knew an individual of this species; and the expression is not so incorrect; as he saw it for three days living out of water, walking about the house in the manner of a dog. The circumstance of the lophius walking out of water has some interest, from showing that relations may subsist between organs apparently the least connected with each other. In this genus, the operculum, which covers the gills, does not open widely, as in most fishes, to let the respired water pass off freely behind; the water is discharged by a small aperture, capable, in Mr Owen's opinion, of being closed by a sphincter muscle; when, the cavities where the branchiæ lie being large, a considerable quantity of water may be confined within them. Thus, not only are the fins of the fish converted into feet, but the gill-covers into pouches, capable of containing water sufficient for respiration when the sea has retired. Then the lophius, lying in the mud or shallow pools, and watching its prey, angles for it in a very curious manner. Pliny relates that it will bury its body, and leaving the glittering filaments which float from its head exposed to view, like worms, will entice the smaller fishes.

But, besides the "harlequin angler," other fishes perambulate the dry land; and even ascend trees (without being carried there by floods). Thus a particular fish (*perca scandens*) can clamber a tree by means of the spines of its gill-covers, and spinous rays of its fins; whence Dr Shaw called it the climbing-fish.†

All animals protected by feathers, or shells, or scales, are endowed with an exquisite sense of touch in the mouth, or in appendages belonging to it. Fishes have hanging from their lips processes called *cirri*, which are equivalent to the feelers or tentacula of insects and crustacea. The fishing lines of the lophius are examples of these processes.

It is surprising how varied are the means by which fishes obtain their food. The bandoulière à bec (*chelmon rostratus*, of

* These fins have two bones like the radius and ulna; but Cuvier says that they are more strictly bones of the carpus.

† The spines of the Echinus, or Sea Urchin, are moveable; they assist in progression. They are directed against an advancing enemy! Although these spines may be effectual for their purposes, they are to be regarded as the lowest, or least perfect substitutes for extremities.

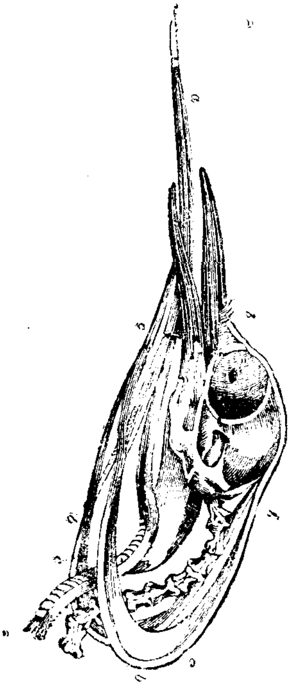
the genus *Chætodon rostratus*), squirts water at flies as they pass, brings them down, and then feeds upon them. The *sciæna jaculatrix*, according to Pallas, possesses a similar skill; and the *sparus insidiator* surprises aquatic insects by the sudden projection of its snout. As to the elongated rays of the dorsal and anal fins in the cordonnier of Martinique (*zeus ciliaris*, le blepharis, Cuv.), some naturalists affirm that they are employed to coil round the stems of plants, in order to sustain the fish. The several offices attributed to these processes in fishes, almost implies that they must possess sensibility, if not muscular power.

Some years ago I discovered, by anatomical investigation and experiment, that, in man, the sensibility of the head and its various appendages, as well as the power of closing the jaws and masticating, depended upon one nerve alone of the ten which arise from the brain, and are distributed within and around the head, viz., the Fifth.* By the aid of comparative anatomy, I found also that a corresponding nerve served similar purposes in the lower animals. In those covered with feathers or scales, or protected by shell, this nerve becomes almost the sole organ of sensation. It gives sensibility to the cirri of fishes, and to the palpi of the crustacea and the antennæ of insects. It is the same nerve which supplies the tongue, and is the organ of its exquisite sensibility to touch, as well as of taste. In some animals, especially reptiles, the tongue, by its length and mobility, becomes a substitute for these external appendages; and in others, besides serving for touch and for taste, it is an organ of prehension. With it the ox gathers in the herbage; and in the giraffe it is curious to observe that, as the whole frame of the animal is calculated to elevate the head to a great height, so the tongue is capable of projecting beyond the mouth to an extraordinary extent, and of wrapping round and pulling down the extreme branches of trees.

[What could have tempted Buffon to express his pity for the woodpecker, as abject and degraded? and why should this bird be described as leading an insipid life, because continually employed in boring and hammering the old stump of a tree? A late naturalist describes the woodpecker as enjoying the sweet

* See the Account of the Author's Discoveries in the Nervous System, at the commencement of the volume.—(S.)

hours of the morning, on the highest branch of the tallest tree, fluttering and playing with his mate and companions. No doubt his diligence, perseverance, and energy in plying his beak are very extraordinary. But, besides the wedge-like strength of the beak, and the power of the neck to strike with it, there is something remarkable in its sensibility. That nerve, the Fifth pair, on which we have shown that all the sensibility of the head depends, transmits along the inside of the mandibles a large branch, which, as it approaches the extremity, perforates

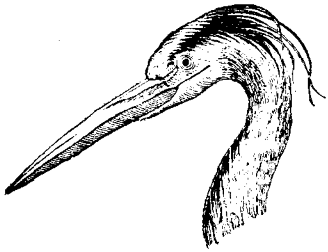

Woodpecker's Tongue.

the bone by innumerable small canals, so as to reach the horny covering. The beak, thus possessed of sensibility, can be used to grope in the crevices of the wood, and under the bark. The woodpecker is enabled by this means, to direct the tongue, which moves with extraordinary celerity, and with a point like a barbed arrow. We have represented the dissection of the head of this bird more accurately in its anatomy than is to be found in books. We offer it because it exhibits a very curious piece of mechanism, adjusted to the tongue, to enable the animal to thrust it out far, and with unusual rapidity. *a*, is the barbed tongue ; *b*, two slender elastic ligamentous cartilages, of very peculiar structure and use ; on one extremity they are attached to the bone which supports the upper mandible ; from this we trace them over the skull down upon the sides of the neck ; and, with a large sweep, turning under the lower mandible, and so continued into the tongue, and not terminating until they reach the horny point, *c c c*, a long muscle which follows these ligamentous cartilages upon their concave side,

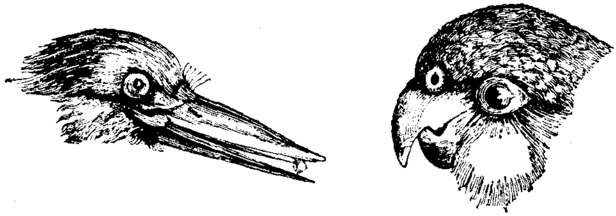
arising from the bone of the lower mandible, and so sweeping round with the cartilages and over the skull, to have another fixed point at the upper mandible: these protrude the tongue. Two muscles are seen to arise from the sides of the larynx, which are the opponents of the last, and retract the tongue. Leaving the other parts of the anatomy, we beg the reader's attention to the action of the muscle *c c c*, which presents one of those curious instances observed in comparative anatomy, of a mechanism adapted to a particular purpose; the tongue is not only thrust out far by this apparatus, but it is shot with great rapidity, in correspondence with its barbed point; this effect is produced by the two extremities of the muscle being fixed points, and the fibres of the muscle itself running on the concave side of the cartilaginous bow, so as to form a smaller circle. We require no mathematical demonstration to prove, that the tongue must be thrust out to a greater distance than the measure of contraction of the muscle. Let us tie the line of the fishing-rod to the last ring of its slender top, and pull upon it at the last ring of the butt: the motion of the top will be very extensive, even when only an inch of the line is drawn through the rings. This is a pretty accurate representation of what takes place by the contraction of this protruding muscle. We have noticed that the upper end of this arch is fixed, the whole motion must therefore be given to the loose extremity in the tongue; and we cannot but observe, that whilst this peculiar arch and muscular ring are adapted for the rapid protrusion of the tongue, its retraction is produced by a common muscle, that is, a muscle running in a straight course. Another curious part of this apparatus is, that a very large gland, which pours out a glutinous matter, is embraced and compressed by the action of the circular muscle. This viscid secretion bedewing the tongue furnishes an additional means for the bird to pick up insects, such as ants, without the necessity of sticking each with its arrow. Nothing can be more mechanical, or more happily adapted to its purpose, than the whole of this structure, and consequently nothing better suited to strengthen our argument. Indeed, it is not inferior to the means employed for giving rapidity of motion to the *membrana nictitans* of the eye of the bird.

With the instrument, as we have before hinted, we should ex-

pect a particular instinctive action, and a corresponding muscular power. As an animal with horns has a powerful neck, so has the neck of the heron, introduced here, an extraordinary muscular power, without which, indeed, the long and sharp bill would be of little use. When the dog approaches the wounded heron, the bird throws itself upon its back, and, retracting its long neck, suddenly darts it out with a force which strikes the bill deep into the dog. If you hold your hat towards the bird, the bill will be struck quite through it. In contending with the hawk, when the latter is spitted, it is not by the rapid descent of the hawk, but by the force with which the heron drives its bill. The strength of the bill of the parrot, and that of all birds which break the stones of fruit or nuts, or hard seeds, is in another direction: the bill is hooked, yet is differently formed from that of the carnivorous bird. The intention is, in the first place, that the point shall play vertically, which, with the strengthening by successive layers of the horny material of the bill



Heron's Bill.



near the point, enables it to break hard objects; and secondly, that by this form the nut or seed may be brought nearer the

joining or articulation of the jaw; which gives the same advantage that we have, when we put a nut nearer the joint of the nut-cracker, that is, nearer the fulcrum. One disadvantage of this form and shortness of the bill would be, that the mandibles could not open wide enough to take in a large seed; but it is provided that the upper mandible shall move upon the skull, as well as the lower one. The form of the bill of the cross-bill looks like an imperfection, but it is attended with real advantages; it is not for crushing, but rather for splitting up a seed into halves, and tearing the cones of the fir-tree. One of the most curious provisions is in the bill of the sea-crow; the mandibles are compressed into the form of simple laminæ, and the lower mandible projects beyond the upper one; so that, as he skims along the water, he dips his bill, and lifts his food, by the most appropriate instrument.]

The whiskers of feline quadrupeds, through branches of the fifth nerve, which enters their roots, possess a fine sensibility. Birds possess it also in a high degree, in their mouths. Ducks, and all that quaffer with their bills under water, have the sense very fine; and in the mandibles there are distributed branches of the fifth nerve, remarkably developed. Animals feel in the whole of their external surface; and of serpents we may say, that when they coil themselves round a body they exercise the organ of touch over their whole length. Still it is the fifth nerve of the brain, or nerves analogous to it, which, in the greater number of animals deficient in extremities, or in proper prehensile organs, ministers to the appropriation of food; the organs may vary in conformation, being sometimes only delicate palpi, sometimes horny processes; but in all, the senses of touch and of taste are bestowed through this—which is the nerve of sensation of the face, tongue, and lips, and the motor nerve of the muscles of the jaws, in man.

But we may repeat, that, necessary as these appendages, and this sensibility, are to the existence of the animals possessing them, the imperfections which they exhibit serve to show, by contrast, how happily the Hand is constructed. Our admiration is increased as we consider the sensibility to various impressions of touch, to varieties in the activity of the muscles, and to changes of posture, possessed by the human hand; and

all united to a facility of motion in the joints, for unfolding and turning the fingers in every possible degree and direction, without abruptness or angularity, and in a manner inimitable by any artifice of springs, pulleys, and levers.

CHAPTER VI.

THE ARGUMENT PURSUED.

So far as we have hitherto proceeded, examining our subject by comparative anatomy, we have been left to conclude that, independently of a system of parts marvellously combined to form the individual animal, another more comprehensive one exists, embracing all animals. However different animals may be in form and bulk, or to whatever condition of the globe they may have been adapted, a uniformity pervades the whole. We have seen no accidental deviation or deformity; but every change has been for a purpose, and every part has had its just relation. In all the varieties, we have witnessed the forms of the organs moulded with such a perfect accommodation to their uses, and the alterations produced in such minute degrees, that all notion of accidental external agency must be rejected.

We might carry our demonstration downward through the lower classes of animals. For example, in insects, we might trace the different modifications of the feet, from their most perfect or complex state, till they disappeared; or, following the changes in another direction, we might pursue them from their smallest beginning to the most perfect condition of the member, where thigh, leg, and tarsus are represented, as in the fly. We should, at first, discern the feet on the bodies of worms as fine cirri, like minute bristles, taking slight hold of the surfaces over which they creep. In the sea-mouse (*aphrodita*), we should perceive these bristles standing out from distinct wart-like processes, which are furnished with appropriate muscles. Then, in the *myriapodes*, the first order of insects, we should see each foot of the "many feet" possessing a distinct articulation. From that, we might pass to insects which have a thigh, leg, and foot, with the most perfect system of flexor, extensor, and adductor muscles; possessing, in fine, all that we most admire in human anatomy. Nay, it is more

curious to observe how the feet of true insects are again changed or modified to assume new offices—the anterior feet becoming feelers, organs of prehension, or *hands*. We thus perceive, that were it our object to examine the delicate and finely-adapted instruments of insects, it would be easy to trace, in almost every one of them, a succession of modifications. Among the vertebrata, we have seen the hand represented by a wing or a fin; so might we discover an opposite change in the wing of an insect. If we began with the fly which has two delicate and perfect wings protected beneath a case, we should find that the covers were capable of being raised, so as to admit of the ready expansion of the wings: in another, the case itself would be converted into a wing, and the fly be characterised by having four wings: proceeding to a third example, we should discover that this anterior wing was larger and more perfect than the posterior: in the fourth specimen, we should find that the posterior wings had disappeared, and that it was furnished with only two perfect ones: if we continued the examination, the next specimen would present an insect deprived of wings altogether. These are not freaks of nature, but new forms of the body; different appendages required for a different kind of poising of the fly in its flight. They are adaptations which succeed each other in the same regular series that has been observed to obtain in the larger animals; in which the intention cannot be mistaken.

A natural question forces itself upon us:—How are those varieties to be explained? The curious adaptation of a single member to different offices, and to different conditions of animals, has led to an extraordinary theory having been propounded in the present day,—that all animals consist of the same "elements." To say that, in every species of animal, however differing in form and structure, the chemical elements entering into the material of which they are formed, is the same, or that the material is attracted and assimilated by the performance of the same vital functions, would be just. But by elements, the authors adverted to mean certain constant pieces, which enter into the structure of the body; and which, they suppose, by being transposed and differently arranged, will explain all the diversities in the forms of animals. They illustrate their views by the analogy of building a mansion.

If there be, they say, a given quantity of materials, and these be disproportionately expended in ornamenting the portico and vestibule, the apartments for the family will be curtailed of their proper dimensions. So, according to the theory, if an elementary piece in an animal occupy a certain place, and be missed in the corresponding place of another animal, it must be sought for in some of the neighbouring organs.

But what foundation is there for saying that the aggrandisement of one member of an animal is attended with a proportional deficiency of another? The advocates of the theory rely much upon examples derived from the study of the bones; but the system fails even in them, as will presently be shown. Meantime, let us ask, is the addition of new parts to the stomach, by which its complexity is greatly increased, as in ruminating animals, attended with a diminution in the length of the intestinal canal, or more simplicity in its structure? On the contrary, is not a complex stomach necessarily connected with a long and irregular intestine? Does a complex intestinal canal render the solid viscera in juxtaposition less perfect? Does the compound heart imply a more simple condition of the lungs?

We have already stated that, in the higher orders of vertebrata, the bones of the shoulder perform a double office; that while they afford a perfect foundation for the motions of the upper extremity, they have an important share in the mechanism of respiration. Let us take an instance where the mode of breathing by the animal is inconsistent with what may be deemed the original design of the bones of the shoulder. In the batrachian order (p. 42), the ribs are absent. Where then, under the guidance of the theory, are we to look for them? If a bone be absent in the cavity of the ear of the bird, it directs us to seek for the bone in the jaw. But when a whole class of animals is deficient in thirty-two ribs, it fails to inform us where these are to be found; or how the supposed "elements" are built up in adjacent structures. If, on the contrary, we adopt the principle, that parts are added or withdrawn, with a never-failing relation to the function to be performed, we can comprehend that if the compages of the chest, to suit the peculiarities of the animal, be removed, and the shoulder be consequently deprived of support, the bones to which the extremity is fixed.

will be expanded and varied both in form and articulation, so as to fulfil the main object of a shoulder,—that of giving security and a centre of motion to the arm.

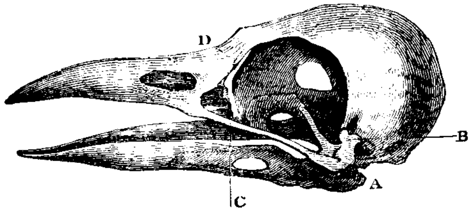
With respect to the instance incidentally noticed, and brought forward as a proof of the excellence of the theory,—the mechanism of the jaw in birds,—it proves the reverse, indeed, of what is assumed. The matter to be explained is simply this. The chain of bones in the ear, which is so curiously adapted, in the mammalia, to convey the vibrations of the membrane of the tympanum to the auditory nerve, is not found in the organ of hearing in birds; there is substituted a mechanism entirely different. The supporters of the theory choose to say that the incus is the one of the four bones of the chain which is absent in the bird: and where, they ask, is it to be found? Here, they reply, in the apparatus of the jaw or mandible; the bone called *os quadratum* is the incus. I believe that the slight and accidental resemblance which the bone B (see figure p. 109) in the bird, has to the incus in man, is the real origin of the fancy.

Let us follow a juster mode of reasoning, and see how the hypothesis in question obscures the beauty of the subject. The first step ought to be, to inquire whether there be any imperfection in the hearing of birds, from want of the incus. That question is easily answered—the hearing of birds is most acute; the slightest noise alarms them; the nightingale, or other bird of song, in a summer evening will answer to the note of his rival, when out of our hearing. We have next to observe another peculiarity in the organ—the absence of an external ear; the presence of which would be at variance with all that we most admire in the shape of the bird, and direction of the feathers, as conducing to its rapid passage through the air. With this obvious defect of the external ear, can we admit that the internal ear is also imperfect—notwithstanding the remarkable acuteness of hearing, which, we know, can result only from the internal structure?

Now, although the structure of the ear of the bird does, in fact, differ from that of the mammalia, yet nothing is wanting. The *columella*, a shaft of bone of exquisite delicacy, extending from the outward membrane of the ear to the labyrinth, or proper seat of the nerve of hearing, occupies the same place, and performs the same office, as the chain of four bones in the ear

of the mammalia: and we have no authority for affirming that the incus, more than any other bone of the chain, is wanting. The sense of hearing is enjoyed by birds in as exquisite a degree as by quadrupeds: the organ is not imperfect; it is a varied apparatus, adapted to a new construction; it is suited to the condition of the bird: and there is no accidental dislocation or substitution.

Let us but look to the mandibles of the bird, and see the use to which this *os quadratum*, supposed by the upholders of the theory to be transposed from the ear, is applied in the apparatus for opening them; and we shall have a most curious example of mechanical adaptation. Indeed, the bill of the bird, in some degree, pertains to our subject, as it is an organ of prehension and of touch. It is withal a fly-trap—hence, its motions must be rapid. Now, the velocity is increased by the most obvious means imaginable,—that is, by giving motion to both mandibles, instead of to one. When a dog snaps, he throws back his head, and thereby raises the upper jaw at the same time that the lower one is dropped; but these are slow and clumsy motions, performed by the muscles of the neck as well as by those of the jaws; and the poor hound makes many attempts before he can catch the fly that teases him. But a swallow or a fly-catcher makes no second effort; the apparatus of prehension which they possess corresponds so admirably to the liveliness of their eye and to their instinct. The mechanism by which such rapidity of motion is attained is this: the muscles which depress



the lower mandible, by the same effort elevate the upper one. A is a process of the lower mandible, projecting behind the centre of motion; accordingly, when the muscle attached to this process contracts, it causes the point of the bill to descend: but

the *os quadratum* (B), situated between the lower mandible and the skull, is at the same time compressed: therefore, a shaft or process (C) from this bone, and which has its anterior extremity fixed against the upper mandible, projects forwards; hence, when the muscle acts, and the os quadratum receives the pressure of the lower mandible, and the process (C) is thrust forward, like a bolt, against the upper mandible, the latter moves upon the skull at (D), and is elevated at the same time that the lower is depressed.* Here, then, is a piece of mechanism as distinct as the lock of a gun, and manifestly intended, as we have said, to give rapidity to the motions of the bill. Now, whether is it nearer the truth to consider this as a new apparatus, suited to the necessities of the creature, or to look upon it as an accidental result of the introduction of a bone, which in its proper office has nothing to do with the jaw?

But we have wandered somewhat from our subject. Let us test the correctness of the theory by attending to the bones which correspond to those of the hand. We have seen that, in animals generally, the same system of bones is preserved, variously modified so as to be adapted to every possible change in office. Now as it is insisted that the number of elements of an organ continues the same, what can be said with regard to the number of bones entering into the paddle, in the saurian and chelonian reptiles? Whilst in man the bones of the wrist and fingers are twenty-seven, and those of the horse only fifteen, the corresponding polygonous bones of the ichthyosaurus (p. 72) are sixty or seventy. Yet, notwithstanding there are in the paddle so many bones, in the part corresponding to the arm and fore-arm, there is only the proper complement. If the system fail us in such an obvious instance, with what confidence can we prosecute the inquiry, under its guidance, into the analogy of the intricate bones of the spine and head.†

In seeking assistance from the works of distinguished naturalists, we do not always find indications of that disposition of mind which we should expect to prevail as a necessary result of

* Another process of the *os quadratum*, directed more internally, assists in raising the upper mandible.

† Since the above criticism, justified by the extravagance of the views propounded at the time, was written, the theory has been essentially modified. See "On the Archetype, and Homologies of the Vertebral Skeleton;" and "Discourse on the Nature of Limbs," by Professor Owen.—(S.)

their peculiar studies ; we miss that combination of genius with sound sense which distinguished Cuvier, and has been ever the characteristic of all great men of science. It is, above all, surprising with what perverse ingenuity some will seek to obscure the conception of a Divine Author, an intelligent, designing, and benevolent Being; how, clinging to the greatest absurdities, they will rather interpose the cold and inanimate influence of some theory of "elements," so as to extinguish in our minds all feeling of dependence, all emotions of gratitude.

Some comparative anatomists there are who will maintain that all varieties in animated beings are the mere result of changes of circumstance, influencing an original animal! They hold that new organs have been produced by a desire, and consequent effort, of an animal, to stretch and mould itself into a shape suitable to the condition in which it is placed;—that, as the leaves of a plant expand to light, or turn to the sun, or as the roots shoot to the appropriate soil, so do the exterior organs of animals grow and adapt themselves! An opinion, as we shall presently find, has prevailed that the organisation of an animal determines its propensities; but the philosophers of whom we now speak, imagine the contrary;—they pretend that, influenced by new circumstances, organs can accommodate themselves, and assume particular forms.

It must be here remarked that there are no instances in the animal kingdom, of new organs being produced by the union of individuals belonging to different species. Nor is there any foundation for the opinion, that new species may be formed by the union of individuals of different families. But it is contended, that, although in the last 5000 years the species of animals have not changed, we cannot tell what may have been the effect of revolutions occurring in the globe before that time; that is, previous to the present condition of the world. On subjects of such a nature, however, we can argue only from what we know, and what we see.

We do, however, perceive, in the conformation of the same animal, surprising changes; some of which are familiar to us. But they all evince foreknowledge and a prospective plan,—an alteration gradually taking place in preparation for, never consequent upon, a new condition. It will suffice for our purpose to take the highest and lowest examples. Man, in the body,

has two conditions of existence; hardly two beings can be less alike than an infant and an adult. Now, the whole fœtal state is a preparation for birth. My readers would not thank me, were I to explain how necessary to his being born alive are the proportions and forms of the infant, as contrasted with those of the full-grown man: yet nothing would be so easy to demonstrate. From the moment of birth, the growth of the body takes a new direction, so that the proportions are changed, and the conformation is accommodated to the erect posture. Few, however, are aware that the life of the child unborn has relation to its condition; and that if the period of birth be protracted beyond the appointed time, it will die, not from a defect of nourishment, but because the period has arrived for a change in its whole economy!

Now, previous to birth, all the organs of the body are being prospectively developed; the lungs becoming perfected, before the admission of air—new tubes constructed, before the flood-gates, which are to admit the blood, are opened. But there are other provisions finer, and more curious, than these. Take any of the grand organs, as the heart or brain; examine it through all its gradations of change in the embryo state, and we shall recognise it, first, as simple in form; then gradually expanding; and finally, assuming the condition peculiar to adolescence. So that it is affirmed, not without the support of a most curious series of observations, that in its earlier stage of growth the human brain resembles that of a fish; next, it bears a resemblance to the cerebral mass of the reptile; in its increase, it is like that of a bird; and slowly, and only after birth, does it assume the proper *form and consistence* of the human brain. But in none of all these stages of development do we see the influence of any supposed law of elementary constituents; or of any other law, than that the order of his development has been so predestined.

If, passing over the thousand instances which might be gathered from intermediate parts of the chain of animal life, we were to proceed to examine the structure of insects, more particularly the metamorphoses they undergo, similar conclusions would be arrived at. For example, if we took the larva of a winged insect, we should perceive in the arrangement of its muscles, and distribution of its nervous system, all the requisite

provisions for its moving over ground. But if, anticipating the metamorphosis, we dissected the same larva immediately before the change, we should find a new apparatus in progress towards perfection; we should see the muscles of its many feet decaying; the nerves to each muscle wasting; a new arrangement of muscles, with new points of attachment, directed to the wings, instead of to the feet; and finally, a new distribution of nerves, accommodated to the members about to be put in motion. Here is no budding or stretching forth of organs, under the influence of surrounding elements; it is a change operated on all the economy, and prospective, that is, in anticipation of a condition which the creature has not yet attained.

These facts countenance the conclusion drawn from the comparative anatomy of the hand and arm—that with each new instrument, visible externally, there are a thousand internal relations established. The introduction of a new mechanical contrivance in the bones or joints, infers an alteration in every part of the skeleton; a corresponding arrangement of all the muscles; an appropriate distribution of the nervous filaments laid intermediate between the instrument and the centre of life and motion; and finally, in relation to the new organ, new sources of activity must be created, otherwise the part will hang an useless appendage.

It must now be apparent, that nothing less than the Power which originally created, is equal to effect those changes on animals, which adapt them to their conditions: and that their organisation is predetermined; not consequent on the condition of the earth or of the surrounding elements. Neither can a property in the animal itself account for the changes which take place in the individual, any more than it can for the varieties in the species. Every thing declares the diversity of species to have its origin in distinct creations; and not to be owing to a process of gradual transition from some original type. Any other hypothesis than that of new creations of animals, suited to the successive changes in the inorganic matter of the globe—the condition of the water, atmosphere, and temperature—brings with it only an accumulation of difficulties.

To fortify what we have said, we ought not to omit bringing into the argument a series of changes of structure altogether

differing from those which we have been hitherto considering,—revolutions in the material of the frame, which take place, without a pause, and during the whole life, in every animal. From no study of the mechanical adaptations of the body, not even from examining the structure and endowments of the organs of the senses, can we obtain a higher idea of the Power which continually superintends the processes of the economy, than from viewing the influence of *life*, in collecting, arranging, and incessantly changing the material of the animal frame. Astounded by the magnitude of natural objects, bewildered by seeing neither beginning nor end, beholding processes of decay alone, persuaded, almost, that everything must be yielded up to a power of destruction,—how useful is it to possess proofs, in the microcosm of the living body, that even when the substance of which that body is composed, is undergoing a ceaseless change, to its minutest elements, the whole animal system may continue in freshness and vigour?

[Is it not surprising that an individual, who retains every peculiarity of body and of mind, whose features, whose gait and mode of action, whose voice, gestures, and complexion we are ready to attest as the very proof of personality,—should, in the course of a few days, change every particle of his solid fabric; that he, whom we suppose we saw, is, so far as his body is concerned, a perfectly different person from him we now see! That the fluids may change, we are ready to allow; but that the solids should be thus ever shifting, seems at first improbable. And yet, if there be anything firmly established in physiology, if there be truth in the science at all, that fact is incontrovertible.

There is nothing like this in inanimate nature. It is beautiful to see the shooting of a crystal; to note the formation of the integrant particles from their elements in solution, and these, under the influence of attraction or crystalline polarity, assuming a determinate shape; but the form here is permanent. In the different processes of elective attraction, and in fermentation, we perceive a commotion; but in a little time the products are formed, and the particles are at rest. In these instances there is nothing like the revolutions of the living animal substance, where the material is alternately arranged, decomposed, and re-arranged.

The end of this is, that the machinery of the body is ever new; that it possesses a property within itself of mending that which was broken, of throwing off that which was useless, of building up that which was insecure and weak, of repelling disease, or of controlling it, and of substituting what is healthful for that which is morbid. The whole animal machinery we have seen to be fragile and liable to injury; now, without this continual change of material, and this new modelling of that material, our lives would be precarious; the texture of our bodies would be spoiled; like some fine piece of mechanism which had stopped, and which no workman had knowledge sufficient to reconstruct. By these living actions the minute particles of the body die successively; not as in the final death of the whole body; but part by part is deprived of vitality, and taken into the general circulation, in order to be cast out of the system; whilst new parts received from the food are endowed with life, and built up in their place. Thus we see that nature, instead of having to establish a new mode of action for every casualty, heals all wounds, unites all broken bones, throws off all morbid parts, by the continuance of its usual operations;.and the surgeon, who is modest in his calling, has nothing to do but to watch, lest ignorance or prejudice interfere with the process of nature. This property of the living body to restore itself when deranged, or to heal itself when broken or torn, is an action which so frequently assumes the appearance of reason, as if it were adapting itself to the particular occasion, that Mr John Hunter speaks of parts of the body as "conscious of their imperfection," and "acting from the stimulus of necessity;" thus giving the properties of mind to the body, as the only explanation of phenomena so wonderful.

The bones of the leg and thigh, which suffer the fatigue of motion, and support the weight of the body, are nevertheless continually undergoing an operation of repair; in which the old particles are withdrawn, whilst new ones replace them, without in the slightest measurable degree diminishing their length, or altering their proper form. We see with what care the walls of a house are shored up, to admit of repair—how correctly the workman must estimate the strength of his pillars and beams—how nicely he must hammer in his wedges, that

every interstice may be filled, and no strain be permitted; and if this operation fail in the slightest degree, it is attended with a rent in the wall from top to bottom. We say, then, that from the very awkwardness of this proceeding, (in which, after all, there is danger of the whole fabric tumbling about the workmen,) we are called upon to admire how the solid pillars in our own frames are a thousand times renewed, whilst the plan of the original fabric is followed, to the utmost nicety, in their restoration. And if it deviate at all, it is only in a manner to surprise us the more: since it will be discovered that the change has been effected with a view to adapt the strength of material to some new circumstance; as the increasing weight which the bone has to support, or the jar it is subject to, from some alteration in the activity or exercise of the body.

There is a living principle, which, while the material changes, is itself permanent; attracting and arranging, dissolving and throwing off successive portions of the solids. And, influencing this living principle, there is a law which shapes, and limits the growth of, every part; and carries it through a regular series of changes, in which its form and aptness for its office are preserved, whilst the material alone is altered. The influence of disease will, for a time, disorder this modelling process, and produce tumours and distortions; but when at length the healthy action—that is, the natural action—prevails, these incumbrances are carried away, and the fair proportions of the fabric are restored.]

Life preserves the materials of the body free from the influence of those affinities which hold the inorganic world together; and it not only does that, but it substitutes other laws. Of the wonders of the microscope, none exceed those presented on looking at the early rudiments of an animal—it may be of the largest creature that inhabits the earth. This rudimentary structure will but appear an homogeneous, transparent, soft jelly; there will be visible in it only a single pulsating point; yet this mass possesses within it a principle of life; and it is not only ordered what this influence shall perform in attracting matter, and building up the complex structure of the body, but even the duration of the animal's existence is from the beginning defined. The term may be limited to a day, and the life be truly ephemeral; or it may be prolonged to a hundred years;

but the period is adjusted according to the condition and enjoyment of the individual, and to the continuance of its species, as perfectly as are the mechanism and structure themselves.

[In a seed, or a nut, or an egg, we know that there is life: from the length of time that these bodies will remain without development, we are forced to acknowledge that this life is stationary or dormant; and that it is limited to the counteraction of putrefaction or chemical decomposition. But no sooner does this living principle become active, than a series of intestinal or internal changes are commenced; which are regularly progressive, without a moment's interruption, while life continues. That principle, which may continue an indefinite number of days, months, or years, without producing any change, begins at once to exhibit its influence, builds up the individual body, regulates the actions of secretion and absorption; and, by its operation upon the material of the frame, stamps it with external marks of infancy, maturity, and age.

Those who say that life results from structure, and that the material is the ruling part, bid us look to the contrast of youth and age. The activity of limb and buoyancy of spirit in youth they consider as necessary consequences of the newness and perfection of the organisation. On the other hand, a ruined tower, unroofed, its walls exposed to be broken up by alternation of frost and heat, dryness and moisture, wedged by the roots of ivy, and toppling to its fall, they compare to old age—with the shrunk limbs, tottering gait, shrivelled face, and scattered grey hair of the old.

But in all this there is no truth. Whilst there are life and circulation, there is change of the material of the frame; and there is a sign of that if a broken bone unite, or a wound heal. Ascribe the distinction to the velocity of circulation, or to the more or less energy of action, or to the rapidity of change; but with the antiquity of the material, it can have nothing to do. The roundness and fulness of flesh, the smoothness, transparency, and colour of the cheek, belong to youth as characteristic of the time of life, not as a necessary quality of the material. Is there a physiognomy in all nature—among birds and beasts, insects and flowers—and shall man alone have no indication of his condition, in the outward form and character? The distinctions in the body apparent in the stages of life, have a

deeper source than the accidental effect of the deterioration of the material of the frame. The same changes which are wrought on the structure of the body in youth and in the spring of life, are going on in the last term of life; but the fabric is rebuilt on a different plan; each stage, from the embryo to the fœtus, the fœtus to the child, from that to adolescence, to maturity, and to old age, has its outward form, as indicative of the season of life, but not of the perfection or imperfection of the gross material. We might as well consider the difference in the term of life of the annual or biennial plant as compared with the oak, or of the ephemeris fly as compared with the bird that hawks at it, to result from the qualities of the matter which form them, as that the outward characters of the different stages of human life, arise from the perfection or imperfection of the material of the body. Not only has every creature its appointed term of life, but parts of the body, in that respect, are independent of the whole; some organs, at their regulated period, shoot to perfection; and at their allotted time, decay, before the failure of the body. What can more distinctly show that so long as the processes of digestion and assimilation go on, the material of the frame is ever decaying, ever renewing, and never older, and never younger? We must conclude that the differences in outward appearances, at the distinct epochs of our life, have been designed as signs which the Creator intended should be interpreted; and that the tenure by which we hold life may be continually before us.

The grand phenomena of nature make powerful impressions on our imagination, and we acknowledge them to be under the guidance of Providence; but it is more pleasing, more agreeable to our self-importance, it gives us more confidence in that Providence, to discover that the minutest changes in nature are equally His care, and that "all things do homage." This exaltation of ourselves is not like the influence of pride or common ambition. We may use the words of Socrates to his scholar, who saw, in the contemplation of nature, only a proof of his own insignificance, and concluded "that the gods had no need of him;" which drew this answer from the sage: "The greater the munificence they have shown in the care of thee, so much the more honour and service thou owest them!"]

When the many beautiful fabrics built up within the anima

body are passed under review, and it is proved that they are not permanent, but are the product of an energy of life, which continues uniform in its operation, whilst all the materials upon which it works are changing—who can hesitate to believe, that the revolutions occurring in the inorganic world around us, are superintended by a presiding Power? The difficulty of comprehension here must be attributed to the partial view of these changes which we can alone obtain. Their fulfilment extends into periods far beyond our measure of time. Nevertheless, we cannot doubt that such a Power does overlook them; and we must acknowledge that a balance is preserved, and that order and harmony prevail.

CHAPTER VII.

OF SENSIBILITY AND TOUCH.

We find every organ of sense, with the exception of that of touch, more perfect in brutes than in man. In the eagle, hawk, gazelle, and feline tribe, the perfection of the eye is admirable; in the dog, wolf, hyæna, as well as birds of prey, the sense of smell is inconceivably acute; and if we hesitate to assign a more exquisite sense of taste to the inferior animals, we cannot doubt their superiority in that of hearing. But in the sense of touch, seated in the hand, man claims the superiority; and it is of consequence to our conclusion that we should observe why it is so.

Some author has said that, accompanying the exercise of touch, there is a desire of obtaining knowledge; in other words, a determination of the will towards the organ of the sense. Bichat avers that touch is active, whilst the other senses are passive. This opinion implies something to be understood—something deeper than what is expressed. We shall arrive at the truth by considering that, in the use of the hand, a double sense is exercised. In touch, we must not only feel the contact of the object; but we must be sensible of the muscular effort made to reach or grasp it in the fingers. It is in the exercise of the latter power, that there is really any effort made. There can be no more direction of the will towards the proper nerve of touch, than there can be towards any sensible nerve. But, before entering on the consideration of the sensibility, and the actions, which belong to the fingers, we must attend to the common sense of feeling in the surface generally.*

Besides that common sensibility is bestowed upon the hand as upon other parts, and some inquiry into it is necessary for our subject, I enter upon its examination the more willingly,

* See the Account of the Author's Discoveries in the Nervous System, at the commencement of the volume. —(S.)

because nothing can afford more surprising proofs of design and benevolence in the Author of our being, than this property. However obviously the illustrations which we have already given, from the mechanism of the body, point to the same conclusion, they are not comparable, in point of interest, to the examples which we are about to present, from the living endowments of the frame.

I have used the term common sensibility, in conformity with the language of authors and customary parlance; but the expressions, "common nerves," and "common sensibility," in a philosophical inquiry, are inadmissible. Indeed, the use of these terms has been the cause of much of the obscurity which has hung over the subject of the nervous system; and of our blindness to the benevolent adaptation of the endowments of that system to the condition of animal existence. Thus it has been supposed that some nerves are but coarsely provided for sensation, while others, of a finer quality, are adapted to more delicate impressions. It has been assumed that the nerve of the eye is finer than the nerve of the finger—without considering that the retina* is insensible to qualities, of which the nerve of touch is cognisant. Nerves are, indeed, appropriated to peculiar senses, and to bestowing distinct functions; but delicacy of texture has nothing to do with that. It is not because the nerve of touch has a coarser or more common texture than the optic or auditory nerve, *that it is insensible to* light or to sound. The beauty and perfection of the system is, that each nerve is susceptible to its peculiar impression only. The nerve of the skin is alone capable of giving the sense of contact, as the nerve of the eye is alone capable of giving vision. If this appropriation resulted merely from delicacy of texture, if the retina were sensible to light only from possessing a finer sensibility than the nerve of touch, the acuteness of the sense would be a source of torment; whereas it is most beneficently provided that the retina shall not be sensible to pain, or be capable of conveying any impressions but those which operate according to its proper function, producing light and colour.

The pain experienced in the eye from irritation of dust, depends on a distinct nerve from that which bestows vision;

* The retina is the expansion of the optic nerve within the eye.

and again, the sensitive nerve of the eye is susceptible to a different kind of impression from the sensation of the body generally; of which more presently. When the surgeon performs the operation of couching for cataract, and the point of the needle passes through the outer coat of the eye, it gives the sensation of pricking, which is an exercise of the nerve of touch; but when the needle passes through the retina, which is the expanded nerve of vision, and forms the internal coat of the eye, it gives the idea of a spark of fire in the eye. The nerve of vision is as insensible to touch, as the nerve of touch is insensible to light.*

We form our notions of sensibility from that of the skin; it is in constant communication with things around us, and affected by their qualities; it affords us information which corrects the ideas received from the other organs of sense, and it excites our attention to preserve our bodies from injury. So familiar are we with the painful effects of injuries upon the surface, that all are apt to imagine that the deeper the injury, the more dreadful the pain. But that is not the fact; nor would it accord with the beneficent design which shines out everywhere. To such irritants as would give the skin pain, the internal parts are totally insensible. The sensibility of the skin not only serves to give the sense of touch to the surface, but it guards the parts beneath; and as the deeper structures cannot be reached except through the skin, and we must suffer pain in it before they can be injured, it would be superfluous to bestow sensibility upon the deeper parts themselves. If the internal organs possessed sensibility similar in kind and degree to that of the integument, so far from answering a useful purpose, it would have been, in the common exercise of the frame, a continual source of pain.

Surgeons, from becoming practically acquainted with a greater number of the phenomena on which physiology is founded than physicians, have perhaps superior opportunities of advancing that science. In performing an operation, the surgeon informs his patient, after he has cut through the skin, that the greatest pain is over; but if, in the advanced stage, he

* These views of the distinct functions of the nerves of sense, were published (1811) in the earliest statement of my observations on the Nervous System.

is obliged to extend the incision, it is properly considered an awkwardness; not only because it proves that he has miscalculated what was necessary to the correct performance of his operation, but because the patient, bearing courageously the deeper incisions, cannot sustain the renewed cutting of the skin, without giving token of severe pain. The fact of the exquisite sensibility of the surface, as compared with the deeper parts, being thus ascertained by daily experience, we cannot mistake the intention: that it is to make the skin the safeguard to the delicate textures within, by forcing us to avoid what will injure the surface. And it does afford a more effectual defence, than if our bodies were clad with the hide of the rhinoceros.

The greater the consideration we give to this subject, the more convincing will be the proofs that the painful sensibility of the skin is a benevolent provision; that it makes us alive to injuries, which would otherwise bruise and destroy the internal vital organs.

In pursuing the inquiry, we learn with much interest, that when bones, cartilages of the joints, or the membranes and ligaments which cover them, are exposed—they may be cut, pricked, or even burned, without the patient, or the animal, suffering the slightest pain. We have arrived at the full comprehension of this subject slowly; disagreeable experiments have been made: but the following is as interesting as it was innocently performed. A man, who had his finger torn off, so as to be connected by the tendon only, came to a pupil of Dr Hunter: "I shall now see," he said, "whether this man has any sensibility in the tendon." He laid a cord along the finger, and blindfolding the patient, cut across the tendon. "Tell me," he asked, "what I have cut?" "Why you have cut across the cord, to be sure," was the answer. At first, these facts would appear to prove, beyond all question, that the structures enumerated are devoid of sensation. After witnessing such remarkable instances of absence of pain, who could come to any other conclusion? But if we adopt the true, philosophical, and, I may say, religious view of the subject, and consider that pain is not conferred as an evil, but, on the contrary, for benevolent and important purposes, we perceive that the subject requires further elucidation.

In the first place, it is obvious, that if a sensibility like that of the skin had been bestowed upon these internal parts, it must have remained unexercised. Had the bones, cartilages, ligaments, or tendons been rendered sensible to pricking or burning, they would have possessed a quality never to be useful; since, without previous warning received through the skin, no such injuries as these could reach them.

But further, allowing pain to be a benevolent provision which admonishes us to avoid such violence as would affect the functions of parts, we may yet inquire whether certain other injuries may not reach these internal structures, without warning from the skin. Now, of this there can be no doubt; the textures around the joints are subject to sprain, rupture, and shocks, while the skin may not be at all implicated in the accident.

Accordingly, notwithstanding the apparent demonstration by experiment that these internal parts are devoid of sensibility, it is evident that they must possess an appropriate kind of feeling, or it would imply an imperfection. Every day's observation shows that such is the case: for we find that the cartilages, ligaments, and tendons, which may be pricked, cut, or burned, without exhibition of pain, are acutely sensible to concussion, stretching, or laceration. Is it not remarkable that men, the luminaries of their profession, should have held that these parts were insensible; and yet that they should have been in daily attendance upon persons suffering from sprained ankle; where the structures injured are the very ones enumerated, and where the pain, felt at the instant of the sprain, is excessive?

How consistent, then, and beautiful is the distribution of this property of life! The sensibility to pain varies with the function of the part. The skin is alive to every possible injurious impression likely to be made upon it; but had the same kind and degree of sensibility been universal,—had the membranes between the bones of our great joints, or the ligaments which knit the bones, or the tendons of the muscles, been sensible in the same manner and degree as the skin, or surface of the eye, we should have been racked with pain in the common movements of the body—the mere weight of one bone on another, or motion of a limb, would have been attended with suffering as acute as that of a man who should attempt to walk in a violent attack of rheumatism. On the other hand, had the deeper struc-

tures possessed no sensibility, we should have been without a guide to our exertions. The internal parts do possess sensibility; but it is limited to warning us of those kinds of injury alone which may possibly reach so deeply. It teaches us what we can do with impunity; if we leap from too great a height, or carry too heavy a burden, or attempt to interrupt a body whose impetus is too powerful, we are admonished of the danger as effectually by this internal sensibility, as of the approach of a sharp point, or a hot iron, to the skin. Accordingly, pain is not given here superfluously: the safe exercise and enjoyment of every part is permitted without alloy: the excess only is restrained.

In continuation of this view of the benevolent object for which pain is awarded, I may be excused for stating the argument as I have delivered it in my lectures :—

"Without meaning to impute inattention or restlessness, I may request you to observe how every one occasionally changes his position, and shifts the pressure of the weight of his body. Were you constrained to keep in one position during the whole hour, you would rise stiff and lame. The sensibility of the skin here guides you to do that which, if neglected, might be followed even by death of the part. When a patient is affected with paralysis of the lower half of the body, we give especial directions to the nurse and attendants to change the position of his limbs at short intervals, to place pillows under his loins and hams, and to shift them often. If these precautions be omitted, you know the consequence to be inflammation of the integument where the pressure is directed; and from that come fever, local irritation, and death.

"Thus you perceive that, without disturbing your train of thought, the natural sensibility of the skin induces you to shift the body, so as to permit the free circulation of the blood in the minute vessels: and when this sensibility is lost, the utmost attention of friends, and the watchfulness of the nurse, are but poor substitutes for the protection which nature is continually affording. If you thus suffer, lying on a soft bed, how could you encounter the rubs and shocks incident to an active life, if deprived of the sense of pain in the skin? You must acknowledge that the sensibility of the integuments is as much a protection to the frame generally, as that of the eyelids is to the

eyes; and the reflection suggests a motive for gratitude which probably you never thought of before."

Sensibility of the hand to the varieties of temperature is a different endowment from that of touch. This property is seated in the skin, and is, consequently, limited to the exterior surface of the body. The internal parts being of uniform temperature, it would have been superfluous to bestow it upon them. As we are surrounded by an atmosphere the temperature of which is continually varying, its extremes might cause the destruction of our frame; and as we must suit our exertions or contrivances to sustain life against such vicissitudes, the possession of this peculiar sensibility affords another proof of a foreknowledge of our condition. To illustrate the evils which might befall us were it not for this sensibility, we might recur to our former example. The paralytic, having no sense of the extremes of temperature is frequently severely burned; or his extremities may be mortified through cold. A man, who had lost this sense in his right hand, but retained muscular power, lifted the cover of a pan, which from falling into the fire was burning hot, and deliberately replaced it, without being conscious of the heat; the effect, however, was that the skin of the palm and fingers was destroyed. The same man had a continual sensation of coldness in the affected arm, which actual cold did not aggravate, nor heat in any degree assuage.*

Sensibility to heat, inasmuch as it is capable of becoming a painful sensation, is not only a safeguard, but a never-failing excitement to activity, and a continual source of enjoyment. Cold braces and animates to exertion, whilst the warmth which is pleasant to us, is genial to all the operations of the animal economy. And here we may remark an adaptation of the living property, very different from a physical influence. Heat is uniform in its effect on dead matter; science informs us that warmth

* There are certain morbid conditions of sensation when cold bodies feel intensely hot.—*Dr Abercrombie's Inquiry into the Intellectual Powers.*

It is a curious illustration of the powers of the cutaneous nerves to receive impressions of the varieties of temperature, that when one is affected by disease anywhere in its course, the sensation of burning may accompany the pain; and the patient will refer the sense of heat to that part of the skin to which the extreme branches of the nerve are distributed. By a burning sensation in the sole of the foot, the surgeon may be directed to disease seated in the centre of the thigh.

and cold are only relative degrees of caloric. But the sensation varies, as heat is given to, or abstracted from, the living body. To the skin, cold and heat are distinct sensations; and without such contrast, we should not continue to enjoy the sense. For in the nervous system it holds universally, that variety, or contrast, is necessary to sensation; the finest organ of sense losing its property by the *continuance of the same impression.* It is by a comparison of cold and heat that we enjoy either condition.

To contrast still more strongly the sensibility of the external surface with the endowments of the internal parts; and to show how very different from what is suggested by first experience the property sensibility generally is, and how admirably varied and accommodated it is to the functions, we shall add one other fact. The brain is insensible—that part of the brain which, if disturbed or diseased, takes away consciousness, is as insensible as the leather of our shoe! That the brain may be touched, or a portion of it cut off, without interrupting the patient in the sentence that he is uttering, is a surprising circumstance! Physiologists formerly inferred, from this fact, that the more important organ of the brain had not been reached. But that opinion arose from the notion that a nerve must necessarily be sensible; whereas, when we consider that different parts of the nervous system possess totally distinct endowments, and that some nerves, as I have elsewhere shown, though exquisitely alive to their proper office, are insensible to touch and incapable of giving pain, we have no just reason to conclude that the brain should be sensible, or exhibit the property of a nerve of the skin. Reason on it as we may, the fact is so;—the brain, through which every impression must be conveyed before it is perceived, is itself insensible. This informs us that sensibility is not a necessary attendant on the delicate texture of a living part, but that it must have an appropriate organ, and that it is an especial provision.*

To satisfy my reader on this interesting subject, I shall contrast two organs, one external and exposed, and the other internal and carefully excluded from injury.

The eye, consisting of its proper nerve of vision, and its trans-

* See the Sensibility of the Retina, "Additional Illustrations."

parent humours and coats, is an organ of exquisite delicacy; and not only is it exposed to all the injuries to which the general surface of the body is liable, but it is subject to be inflamed and rendered opaque by there getting into it particles so light that they float in the atmosphere, and to the contact of which the common skin is quite insensible. Now the mechanical, and more obvious contrivance for the protection of this organ, is a ready motion of the eyelids, and the shedding of tears; which tears, coming, as it were, from a small fountain, play over the surface of the eye, and wash away whatever is offensive. But to regulate the action of this little mechanical and hydraulic apparatus, an exquisite sensibility is required—not that kind which enables the eye to receive the impressions of light, and may at times warn it of approaching danger, but a property which more resembles the tenderness of the skin, yet is happily adapted by its fineness to the condition of the organ.

If the excitement which puts in motion the mechanism for guarding the eye, depended on our will—if it were not an influence quicker than thought—the apparatus would be unavailing. It is not by feeling the pain of the offensive body, estimating its dangers, and acting on the conviction, that we close the eyes to avoid injury. That would be all too slow for the purpose. When a light, foreign body touches the eyelashes, seated on the tender extremities of sensitive nerves, they give alarm; and more swiftly than an act of volition, they cause a motion both of the eyelids and eyeballs, even before the offending body can touch the eye's surface.

It sometimes happens that the nerve which bestows this appropriate sensibility on the external surface of the eye, and sends its branches into the roots of the eyelashes, is injured, and deprived of its functions; and the consequences are distressing. Smoke and offensive particles afloat in the atmosphere enter and rest upon the eye, or flies and dust lodge under the eyelids; but without producing sensation, and without exciting either the hydraulic or mechanical apparatus to act in expelling them. Yet, although these objects do not give pain, they irritate the surfaces and produce inflammation; that causes opacity of the fine transparent membranes of the eye, and the organ is lost, even when the proper nerve of vision remains entire. I have seen many instances of the eye being thus deprived

of sensibility to touch;* and on these occasions, before the transparency of the organ was lost, it has been singular to remark, that when the hand was waved before the eye, or a feather brought near it, the person shut the eye; yet when the finger was put into the eye, and rubbed the surface, or when blood was drawn from the inflamed vessels by the lancet, he did not even wink. That is, when the sense of vision, through the optic nerve, gave notice of danger to the organ, the patient winked to avoid it; but the sense of touch being lost, there was no pain felt, nor alarm given by the sensitive nerve, and the action of winking was not excited to defend the organ.

I shall present another instance of the peculiar nature of the sensibility which protects the eye. Every one knows that if the eye be touched by a thing of the lightness of a feather, the muscles will be thrown into uncontrollable action and spasm. But the oculist has observed that if he pass the point of his finger somewhat rudely between the eyelids, and press directly against the eye, he will produce hardly any sensation—certainly no pain—and he can hold the ball steady for his intended operation! This is one of the little secrets of the art. The oculist can turn out the eyelids, and finger the eye in a manner which appears at once rude and masterly: and still the wonder grows that he can do such things dexterously, and without inflicting pain, when daily experience makes us feel that even a grain of sand will produce exquisite torture. The explanation is, that the eye and eyelids possess a sensibility adjusted to excite the action of its protecting parts against the intrusion of such small particles as might lodge, and inflame its finer membranes: but the apparatus is not calculated to defend the surface against the injury of a stick or stone. From such accidents the eye could not be saved by a delicate sensibility and an involuntary action; they call for an exertion of the will.

These details afford new proofs of the exact relation established between the kind of sensibility belonging to an organ, and the end to be attained through it. Were it not for the pain to which the eye is exposed, we should soon lose the enjoyment of the sense of vision altogether. But we are about to institute a comparison between the eye and the heart.

* They are stated at length in the Author's work on the Nervous System.—(S.)

The observation of the admirable Harvey, the discoverer of the circulation of the blood, is to this effect. A noble youth of the family of Montgomery, from a fall, and consequent abscess on the side of the chest, had the interior marvellously exposed; so that after his cure, on his return from his travels, the heart and lungs were visible, and could be handled: which when it was communicated to Charles I., he expressed a desire that Harvey should be permitted to see the youth, and examine his heart. "When," says Harvey, "I had paid my respects to this young nobleman, and conveyed to him the King's request, he made no concealment, but exposed the left side of his breast, when I saw a cavity into which I could introduce my fingers and thumb; astonished with the novelty, again and again I explored the wound, and first marvelling at the extraordinary nature of the cure, I set about the examination of the heart. Taking it in one hand, and placing the finger of the other on the pulse of the wrist, I satisfied myself that it was indeed the heart which I grasped. I then brought him to the King, that he might behold and touch so extraordinary a thing, and that he might perceive, as I did, that unless when we touched the outer skin, or when he saw our fingers in the cavity, this young nobleman knew not that we touched the heart."

Other observations confirm this great authority, and the heart is declared insensible. And yet the opinions of mankind must not be lightly called in question. Not only does every emotion of the mind affect the heart, but every change in the condition of the body—motion during health—the influence of disease—is attended with a response in the action of the heart.

Here is the distinction manifested, to which we desire the reader's attention. The sensibility of the surface of the eye is for a purpose; so is that of the heart. Whilst the sensibility of the eye guards it against injury from without, the heart, insensible to touch, is yet alive to every variation in the circulation, to every alteration of posture, or of exertion, and is in sympathy, of the strictest kind, with the constitutional powers.

When we consider these facts, we can no longer doubt that the sensibilities of the living frame are appropriate endowments; not qualities necessarily arising from life; still less the consequences of delicacy of texture. Nor can we, I should hope,

longer doubt that they are suited to the condition, and especially to the degree of exposure, of each part, and destined for the protection of the different organs. We perceive that they vary in an extraordinary manner, according as they are given to external or to internal parts; as they belong to one apparatus of action, or to another; and they are ever adapted to excite some salutary or necessary action. We find no instance of pain being bestowed as a source of suffering or punishment purely, or without finding it overbalanced by great and essential advantages—without, in short, being forced to admit that there could be no protection more perfect for the part. We perceive that the more an organ is exposed, or the greater the delicacy of its organisation—the more exquisitely contrived is the apparatus for its defence, the more peremptory the call for the activity of that mechanism: and as in such instances, the motive to action admits of no thought or hesitation, the action itself is more instantaneous than the quickest suggestion or impulse of the will.

We are speaking of the natural functions of the body. It requires a deeper consideration—indeed it is foreign to my subject—to advert to the pains which result from disease; or to reconcile those who suffer in an extraordinary degree to the dispensations of Providence. But as a witness I may speak. It is my daily duty to visit certain wards of the hospital, where no patient is admitted but with a complaint that more than any other fills the imagination with the idea of insufferable pain and certain death. Yet these wards are not the least remarkable for the composure and cheerfulness of their inmates. The individual who suffers has a mysterious counter-balance to that condition, which, to us who look on, appears attended with no alleviating circumstance.

It *affords an instance of the boldness with which philosophers* have questioned the ways of Providence, that they have asked—why might not all our actions be performed at the suggestion of pleasure? why should we be subject to pain at all? In answer, I would say, that consistently with our condition, our sensations and pleasures, there must be variety in the impressions. Such contrast is common to every organ of sense. The continuance of an impression occasions it to fade. If the eye look steadfastly upon one object, the image is soon lost—if we

continue to look on one colour, we become insensible to it; and for a perfect perception, colours opposed to each other are necessary.* So have we seen that in the sensibilities of the skin, variety is required to render the sensations perfect.

It is difficult to say what these philosophers would define as pleasure. But whatever exercise of the senses it may be, unless we are to suppose an entire change of our nature, its opposite must also be implied. Nay, further, in this fanciful condition of existence did anything of our present constitution prevail, we must suppose, that emotions purely of pleasure would lead to indolence, relaxation, and indifference. In the lower creatures, governed by instinct, there may be, for aught we know, some such condition of existence. But the complexity and delicacy of the human frame are necessary for sustaining those powers or attributes which are in correspondence with superior intelligence; since they are not in relation to the mind alone, but intermediate between it and the external material world. Grant that vision is necessary to the development of thought, the organ of it must be formed with relation to light. Speech, so necessary to the development of the reasoning faculties, implies a complex and exceedingly delicate organ, to play on the atmosphere around us. It is not to the mind that the various organisations are wanted; but to its condition as related to a material world.

The necessity for this delicacy of the animal structure being admitted, the textures must be preserved by modifications of sensibility, which shall either excite the parts to instinctive efforts, or rouse us to instantaneous voluntary activity. Could the eye guard itself, unless it possessed sensibility greater than the skin; or unless this sensibility were in consent with an apparatus which acts as quickly as thought? Could we, by the mere influence of pleasure, or by any cessation or variation of pleasurable feelings, be kept alive to those injuries to which the lungs are exposed from substances being carried into them with the air we breathe? Would anything but the painful sense which accompanies the danger of suffocation, produce those instant and sudden efforts which guard the throat from the intrusion of offensive or injurious matters? Pleasure is, at the best, a poor motive to exertion; and rather induces languor and indulgence, and at length indifference. To say that animals

* See Additional Illustrations in the Appendix.

might be continually in a state of enjoyment, and that when urged by necessities such as thirst, hunger, and weariness, they might merely feel a diminution of pleasure, is to suppose not only their nature, but that of the external world, altered. Whilst earth, rocks, woods, and water are the theatre of our existence, the textures of our bodies must be exposed to injuries: and they can only be protected from them by sensibilities adapted to each part, and capable of rousing us to the most animated exertions. To leave us to the guidance of the solicitations of pleasure, would be to place us where accident would befall us at every step; and whether these injuries were felt or not, they would be destructive to life.

In short, to suppose that we might move and act without experience of resistance or of pain, that there should be *nothing to* bruise the skin, or hurt the eye, and nothing noxious to be inhaled with the breath, would be to imagine another state of existence altogether from the present; and the theorist would be mortified were that interpretation put on his meaning. Pain is the necessary contrast to pleasure: it ushers us into existence, and is the first to give us consciousness: it alone is capable *of exciting the organs into activity: it is the companion* and the guardian of human life. If all were smooth in our path, if there were neither rugged places nor accidental opposition, whence should we derive those affections of our minds which we call enterprise, fortitude, and patience?

Independently of pain, which protects us more powerfully than a shield, there is inherent in us, and for a similar purpose, an *innate* horror of death. "And what thinkest thou," said Socrates to Aristodemus, "of this continual love of life, this dread of dissolution, which takes possession of us from the moment we are conscious of existence?" "I think of it," answered he, "as the means employed by the same great and wise artist, deliberately determined, to preserve what he has made."

The reader will, no doubt, observe here the distinction. We have experience of pain from injuries, and we learn to avoid them. But we can have no experience of death. Therefore the Author of our being has implanted in us an innate horror at dissolution; and we may see the same principle extending through all animated nature. Where it is possible to be taught by experience, we are left to profit by it; but where

we can have none, feelings are engendered without it. And this is all that was necessary to show how the life is guarded; sometimes it is by mechanical strength, as in the skull; sometimes by acute sensation, as in the skin and in the eye; sometimes by innate affections of the mind, as in the horror of death: and these will prevail, as the voice of nature, when we can no longer profit by experience.

The highest proof of benevolence is this: that we possess the chiefest source of happiness in ourselves. Every creature has pleasure in the mere exercise of his body, as well as in the languor and repose that follow exertion. But these conditions are so balanced, that we are impelled to change; and every change is an additional source of enjoyment. What is apparent in the body is true of the mind also. The great source of happiness is to be found in the exercise of talents; and perhaps the greatest of all is when the ingenuity of the mind is exercised in the dexterous employment of the hands. Idle men do not know what is meant here; but nature has implanted in us this stimulus to exertion; so that the ingenious artist who invents, or with his hands creates, enjoys a source of delight, perhaps greater, certainly more uninterrupted, than belongs to the possession of higher intellectual powers; far at least beyond what falls to the lot of the mere minion of fortune.

CHAPTER VIII.

OF THE SENSES GENERALLY, INTRODUCTORY TO THE SENSE OF TOUCH.

ALTHOUGH we are most familiar with the sensibility of the skin, and believe that we perfectly understand the nature and mode of conveyance of the impressions received upon it to the sensorium, yet there is a difficulty in comprehending the operations of the other organs of the senses—a difficulty not removed by the apparent simplicity of that of touch.

There was a time when the inquirer was satisfied by finding in the ear a little drum, and a bone to play upon it, with an accompanying nerve ; this was deemed a sufficient explanation of the organ of hearing. It was thought equally satisfactory if, in experimenting upon the eye, the image of the object were seen painted at the bottom, on the surface of the nerve. But although the impression can be thus traced to the extremity of the nerve, still nothing is comprehended of the nature of that impression, or of the manner in which it is transmitted to the sensorium. On the most minute examination of the nerves, in all their course, and where they are expanded in the external organs of the senses, they seem to be the same in substance and in structure, whatever be their function. Whether the disturbance of the extremity of the nerve that gives rise to the sensation, be a vibration, or an image painted upon the surface, it cannot, in either case, be transmitted to the brain according to any physical laws that we are acquainted with. All that we can say is, that the different affections of the nerves of the outward senses, are the signals which the Author of nature has willed to be the means by which correspondence is held with the realities. The impression on the nerve can have no more resemblance to the ideas suggested in the mind, than there is between the sound and the conception, in the mind of that man who, looking out on a dark and stormy sea, hears the report of can-

non, which conveys to him ideas of despair and shipwreck—or between the light received into the eye, and the idea excited in one who, apprehending national convulsion, sees a column of flame afar off, which to him is the signal of actual revolt.

Such illustrations, it may be said, rather tend to show how independent the mind is of the organs of the senses. That a tumult of ideas should arise from an impression on the retina, not more intense than that produced by a burning taper, may be regarded as an instance of excited imagination. But even in a common act of perception, the determined relations between the sensation and the idea in the mind have no more actual resemblance. How this consent, so precise and constant, is established, can neither be explained by physiology nor any mode of physical inquiry whatever.

From this law of our nature, that certain perceptions originate in the mind in consequence of the impressions on corresponding nerves, it follows, that one organ of sense can never become the substitute for another, so as to excite the same ideas. When an individual is deprived of the organs of sight, no power of attention, or continued effort of the will, or exercise of the other senses, can enable him to enjoy the class of sensations which is lost. The sense of touch may have its delicacy increased in an exquisite degree; but if it be true, as has been asserted, that individuals can distinguish colours by touch, it can only be by their feeling a change upon the surface of the stuff, and not by any perception of the colour. It has been my painful duty to attend on persons who have feigned blindness, and pretended that they could see with their fingers: but I have ever found that these first deviations from truth entangled them in a tissue of deceit; and they have at last been forced into admissions which showed their folly and weak inventions. When such patients were affected with nervous disorders, producing extraordinary sensibility in their organs,—as a power of hearing much beyond our common experience,—they became objects of pity; this acuteness of sensibility, from its exciting interest and wonder, has gradually led these morbidly-affected persons to pretend to powers greater than they actually possessed; and it has been difficult to distinguish the symptoms of disease, from the supposed gifts of which they boasted.

Experiment proves, as we have already stated, that each organ

of sense is appropriated to receive a particular kind of sensation only; and that the nerves intermediate between the brain and the outward organs respectively, are capable of receiving no other sensations but such as are proper to their particular organs. Every impression on the nerve of the eye, or of the ear, or of smelling, or of taste, excites only perceptions of vision, of hearing, of smelling, or of taste; not simply because the extremities of these nerves individually are suited to one kind of external impression; but because the nerves, through their whole course, and wherever they are affected, are capable of communicating the idea to which they are appropriated, and no other. A blow on the head, an impulse quite unlike that for which the organs of the senses are provided, will excite them all in their several ways; besides the pain, there will be sparks of fire in the eyes, and a loud noise in the ears. An officer received a musket-ball which went through the bones of his face—in describing his sensations, he said that he felt as if there had been a flash of lightning, accompanied with a sound like the shutting of the door of St Paul's.

It is owing to the circumstance of every nerve being appropriated to its function, that the false sensations which accompany the morbid irritation of the nerves from internal causes, are produced—such as flashes of light, ringing of the ears, bitter tastes, or offensive smells. These sensations are caused by derangement of some internal organ, most frequently the stomach, exciting the respective nerves of sense.

Nothing affords a more perfect proof of power and design, than the confidence all men put in the correspondence between the perceptions or ideas that arise in the mind, through the exercise of the organs of the senses, and the qualities of external matter. Although it must ever be beyond our comprehension, how the object presented to the outward sense and the idea of it are connected, they are, nevertheless, indissolubly united; so that the knowledge of the object, gained by these unknown means, is attended with an absolute conviction of the real existence of the object—a conviction independent of reason, and to be regarded as a first law of our nature.

In the percipient or sentient principle residing in the brain and nerves, as well as in the organs of sense, there must be a conformity to the impression, and a correspondence with the

qualities of matter. The organs of sense may be compared to so many instruments, or tests, which the philosopher successively employs for distinguishing the different properties of a body which he investigates: as all the qualities are not communicable through any one, he has recourse to several: and so in the use of the senses, each organ is provided for receiving a particular impression, and no other. However mortifying it may be to acknowledge that we know nothing of the manner in which sensation is propagated, or the mind ultimately influenced, it is nevertheless pleasing to observe the correspondence established, through a series of organic parts, between the mind and the condition or qualities of matter in the external world. Nothing can convey a more sublime idea of Power; and of the unity of the system which embraces the organic and the inorganic creations.

Returning to the consideration of the sensibility of the skin, or the sense of touch: it is as distinct an endowment as the sense of vision; it is neither inferior nor more common. Touch is not consequent upon the mere exposure of the delicate surface of the animal body. It is a sense the organ of which is seated in the skin; and although the organ is necessarily extended widely over the surface of the body, yet the nerves are as appropriate as if they were gathered into one trunk, like those belonging to the organs of vision and hearing. In fact, we do find that the portion of nervous matter on which the sensation of touch depends, however diffused in its sentient extremities over the whole exterior surface, is concentrated towards the brain, and is there appropriated to raising its own peculiar perceptions in the mind.

Perhaps this will be better understood from the fact that a certain large portion of the skin may be the seat of excruciating pain, and yet the surface, which to the patient's idea is the seat of pain, will be altogether insensible to cutting, burning, or any mode of destruction! "I have no feeling in all the side of my face, and it is dead; yet surely it cannot be dead, since there is a constant pricking pain in it." Such were the words of a young woman whose disease was at the root of the nerve of sensibility near the brain.* The disease had destroyed the power of the nerve to convey sensation from the exterior; but by pro-

* See the Author's work on the Nervous System.—(S.)

ducing irritation near its root, it had substituted that morbid impression, which was referred to the tactile extremities of the nerve.

If we use the term "common sensibility," we can do so only in reference to touch: since, from being the most necessary of the senses, it is enjoyed by all animals, from the lowest to the highest in the chain of existence. Whilst this sense is distinct from the others, it is the most important of any; for it is through it alone that some animals possess the consciousness of existence; and to those which enjoy many organs of sense, that of touch, as we shall presently show, is essential to the full development of the powers with which they are endowed.

OF THE ORGAN OF TOUCH.

Touch is that peculiar sensibility which gives the consciousness of the resistance of external matter, and makes us acquainted with the hardness, smoothness, roughness, size, and form, of bodies. While it enables us to distinguish what is external from what belongs to us, and informs us of the geometrical qualities of bodies, we must refer to this sense also our judgment of distance, of motion, of number, and of time.

Premising that the sense of touch is exercised by means of a complex apparatus—by a combination of the consciousness of the action of the *muscles*, with the sensibility of the proper nerves of touch, we shall, in the first place, examine in what respect the organisation resembles that of the other senses.

We have said before, that, on the most minute examination of the extremities of the nerves expanded on the different organs of sense, no appropriate structure can be detected; that they appear everywhere the same,—soft, pulpy, prepared for impression, and so distributed that the impression shall reach them. What is termed the structure of the organ of sense, is that apparatus by which the external impression is conveyed inwards, and by which its force is *concentrated on the extremity* of the nerve. The mechanism by which the external organs are suited to their offices is highly interesting; from their resembling things of human contrivance, they serve to show, in a way level to our comprehension, the design with which the fabric is constructed. Thus we can understand how the eye is so seated and so formed as to embrace the greatest possible field of vision;

we can estimate the happy effects of the convexity of the transparent cornea, and the influence of the three humours, of various densities, acting like an achromatic telescope; we can admire the precision with which the rays of light are concentrated on the retina, and the beautiful provision for enlarging or diminishing the pencil of light, in proportion to its intensity. But all this explains nothing, in respect to the perception raised in the mind by the impulse on the extremity of the nerve.

In like manner, in the complex apparatus of the ear, we see how the organ is formed with reference to a double course of vibrations,—as they come through the atmosphere, and through the solids of the body itself: we comprehend how the undulations and vibrations of the air are collected and concentrated; how they are directed, through the intricate passages of the bone, to a fluid in which the nerve of hearing is suspended; and we see how, at last, that nerve is moved. But nothing more can we comprehend from the study of the external organ of hearing.

The illustration is equally clear as regards the organ of smelling or that of taste. There is nothing in the nerve itself, either of the nose or the tongue, which can explain why it is susceptible of the particular impression that it receives. For these reasons, we are prepared to expect very little complexity in the organ of touch; and to believe that the peculiarity of the sense consists more in the property bestowed on the nerve, than in the mechanical adaptation of the exterior organ.

OF THE CUTICLE.

The cuticle or epidermis covers the true skin, excludes the air, limits the perspiration, and in some degree regulates the heat of the body. It is a dead or insensible covering; it guards from contact the true vascular surface of the skin; and in this manner, it often prevents the communication of infection. We are most familiar with it as the scarf skin, which scales off after fevers, or by the use of the flesh-brush, or by the friction of the clothes; for it is continually separating in minute thin scales, whilst it is as regularly formed anew by the vascular surface below.

The structure of this covering is intimately connected with the organ of touch. The habit of considering the function of

certain textures as produced accidentally, has induced some anatomists to believe that the cuticle is formed by the mere hardening of the true skin. The fact, however, that the cuticle is perfect in the new-born infant, and that even then it is thickest on the hands and feet, should have shown that, like every thing in the animal structure, it participates in the great design.

The cuticle is so far a part of the organ of touch, that it is the medium through which the external impression is conveyed to the nerve; and the manner in which that is accomplished is not without interest.

The extremities of the fingers best exhibit the provisions for the exercise of the sense. The nails give support to the tips of the fingers; and in order to sustain the elastic cushion which forms their extremity, they are made broad and shield-like.* This cushion is an important part of the exterior apparatus; its fulness and elasticity adapt it admirably for touch. An ingenious gentleman has observed that we cannot feel the pulse at the wrist with the tongue. That is a remarkable fact; and I apprehend that it is owing, not to the insensibility of the tongue, but to its softness of texture; the tip of the tongue is not fitted to receive that peculiar impulse, to which the firm and elastic pad of the finger is so perfectly suited. Is it not interesting to find that, had the organ of touch been formed as delicately as the tongue, we should have lost one of our inlets to the knowledge of matter!

But to return: on a nearer inspection, we discover in the points of the fingers a more particular provision for adapting them to touch. Wherever the sense of feeling is most exquisite, there we see minute spiral ridges of the cuticle. These ridges have corresponding depressions on the inner surface; and they, again, give lodgment to soft pulpy processes of the skin, called papillæ, in which lie the extremities of the sentient nerves. Thus the nerves are adequately protected, while they are, at the same time, sufficiently exposed, to have impressions communicated to them through the elastic cuticle, and thus to give rise to the sense of touch. The organisation is simple, yet it is in strict analogy with the other organs of sense.

Every one must have observed a tendency in the cuticle to

* *Unguis scutiformis.*

become thickened and stronger by pressure and friction. If the pressure be partial and severe, the action of the true skin is too much excited, fluid is thrown out, and the cuticle is raised in a blister. If it be still partial, but more gradually applied, a corn is formed. If, however, the general surface of the palms or soles be exposed to pressure, the cuticle thickens, until it becomes a defence, like a glove or shoe. Now, what is most to be admired in this thickening of the cuticle is, that the sense of touch is not thereby lost, or indeed much diminished, certainly not in proportion to the increased protection afforded by it to the skin beneath.

The thickened cuticle partakes of the character of the hoof of an animal. We may therefore examine the structure of the hoof of the horse, as the best illustration how the sensibility of the skin is preserved in due degree, whilst the surface is completely guarded against injury. The human nail is a continuation of the cuticle, and the hoof of an animal belongs to the same class of parts as the nail.

In observing how the nerves are disposed with regard to the hoof, we have, in fact, a magnified view of the structure which exists, only more minutely and delicately, in the cuticular covering of the fingers. The crust or hoof is in itself altogether insensible: but on separating it from the part which it covers, we perceive that its inner surface is marked by numerous grooves or fissures. On the other hand, the surface with which the hoof is in contact, possesses, during life, a high degree of vascularity and sensibility; and projecting from it are small villi,* containing blood-vessels and nerves, which enter into the fissures of the hoof, where they are securely lodged. When we detach the hoof from the vascular and nervous surface, we can see these delicate tufts or villi, as they are pulled out from the interspaces which they occupied: and they are not merely extremities of nerves; they consist of nerves with the necessary accompaniment of membrane and blood-vessels, on a very minute scale: for it must be remembered that nerves can perform no function unless supplied with blood, all qualities of life being supported through the circulating blood. The nerves so prolonged within the villi

* VILLI, delicate tufts, like the pile of velvet, projecting from the surface of any membrane.

into the hoof, receive the vibrations of that body: and by that means the horse is sensible to the motion and pressure of its foot, or to its percussion against the ground; without which provision, there would be a certain imperfection in the limb.

In a former part of this treatise, I have shown by what a curious mechanism the horse's foot is rendered yielding and elastic, to enable it to bear the shocks to which it is liable. But owing to the hardness of our made roads, and the defects of shoeing, the pressure and concussion are too severe and too incessant not to be attended with injury of the foot: accordingly, inflammation follows; and then the protecting sensibility is converted into a source of pain; the horse is "foundered." There is a remedy for this condition, by dividing the nerve across before it reaches the foot; the consequence of which operation is, that the horse, instead of moving with timid steps, puts out his feet freely, and the lameness is cured. But were we to leave the statement thus barely, the fact would be opposed to the conclusion, that for the perfection of the instrument, the mechanical provision and sensibility are equally necessary, and require to be associated. It may relieve us from the difficulty, if we consider that pressure against the sole and crust is essential to the play of the foot, and to its perfection: when the foot is inflamed, and the animal does not put it freely down, it does not bear its weight upon the hoof so as to bring all the parts into action; hence contraction is produced, the most common defect, as we before said, of the horse's hoof. But when the animal is relieved from its pain by the division of the nerve, it then uses the foot freely, and use restores all the natural actions of this fine piece of mechanism.

It is obvious, however, that when the nerve is cut across, there must be a certain defect; the horse will have lost his natural protection, and must now be indebted to the care of his rider. He will not only have lost the sense of pain to guard against over-exertion, but the feeling of the contact of the ground, necessary to his being a safe roadster.

The teeth are endowed with sensation, and in the same manner as the hoof of the horse. Although neither the substance nor the enamel of the tooth is itself sensible, yet a branch of the sensitive nerve (the fifth) enters into the cavity of each tooth; a vibration can thus be communicated through

the tooth to the nerve; and the smallest grain between the teeth is easily felt.

To return to the human hand. If a man use the fore-hammer, the cuticle of his fingers and palm will become thickened in a remarkable manner; but the grooves on the inner surface become also deeper, and the papillæ, projecting into them, longer; the consequence of which is, that owing to the cuticle retaining its aptitude to convey impressions to the included nerves, he continues to possess the sense of touch in a very useful degree.

In the foot of the ostrich,* we may behold a magnified view of the cuticle, with processes disposed like the thickset hairs of a brush, each process enclosing a papilla, into which the lengthened nerves are prolonged. The outer skin of the foot, in this "runner," almost equals in thickness the hoof of the horse. In separating it from the skin, the papillæ, containing within them the nerves, are withdrawn from each of the processes of cuticle, and leave corresponding foramina or pores. If the object had been merely to protect the foot by an insensible covering, it would have sufficed to invest the sole with a succession of dead layers of cuticle; and that would have been the case had the scarf skin been simply thickened by pressure; but the structure is adapted in all respects to the habits of the bird: besides having adequate callosity, it is endowed with sensation proportioned to its wants.

Such, then, is the structure of the organ of touch: obvious in the extremities of the fingers; magnified in the foot of the horse, or of the ostrich; and existing even in the delicate skin of the lips.

I have casually noticed that increased vascularity, as being necessary to sensibility, always accompanies the distribution of nerves to a part. In the museum of the College of Surgeons, we see that Mr. Hunter had taken pains to demonstrate this, by injecting the blood-vessels of a slug; although the coloured size was injected from the heart, the blush of the vermilion extends principally over its "foot;" the foot, in these gasteropoda, being the whole lower flat surface or belly on which the animal creeps. This vascular surface is also the organ of touch, by

* See engravings, pp. 66, 87.

which the slug feels and directs its motions. It is the same principle, if we may compare such things, that explains the rosy-tipped fingers and ruby lips; the colour implies that high vascularity is combined with the fine sensibility of these parts.

Having described the relation of the cuticle to the nerves in the organ of touch, we may notice the advantages which accrue from the roughness of its surface. We must be sensible that on touching a finely polished object, the sense is but imperfectly exercised, compared with touching or grasping a rough and irregular body. Had the cuticle been perfectly smooth, it would have been ill suited to touch; but being, on the contrary, slightly rough, its quality is more adapted to convey sensation.

A provision for increasing friction is especially necessary, in some parts of the skin. Thus, the roughness of the cuticle in the palm of the hand, and in the sole of the foot, gives us a firmer grasp and a steadier footing: nothing is so little apt to slip, as the thickened scarf-skin, either of the hand or foot. In the hoofs of animals, as might be expected, roughness and tenacity in the structure are further developed. It is owing to this quality that the chamois, ibex, or goat, steps securely at great heights on the narrow ledges of rocks, where it would seem impossible to cling. So in the pads or cushions of the cat, the cuticle is rough and granular; and in the foot of the squirrel, indeed of all animals which climb, we find the pads covered with the cuticle, similarly roughened, allowing them to descend the bole of the tree securely, while their claws enable them to grasp and cling to the branches.

In concluding this section, we perceive that the organ of touch consists of nerves, appropriated to receive impressions of contact from bodies capable of offering resistance. Fine filaments of sensitive nerves, wrapped up in delicate membrane, with their accompanying arteries and veins, project from the true skin into papillæ on the surface, and these again are lodged in corresponding grooves or foramina of the cuticle. The filaments are not absolutely in contact with the cuticle, but are surrounded with a semi-fluid matter; by which and the cuticle the nerves are protected, at the same time that they are sensible

to pressure, cutting, pricking, and heat. But this capacity, we repeat, is not owing, strictly speaking, to anything in the structure of the organ; it is to the appropriation of the nerve to this class of sensations.

CHAPTER IX.

OF THE MUSCULAR SENSE.

A NOTION prevails that although the young of the lower animals are directed by instinct, there is an exception in regard to the human offspring. It is believed that in the child we may trace the gradual dawn and progressive improvement of reason, independently of instinct. That is not true. We doubt whether the actions of the body, if not first instinctive, or directed by sensibilities which are innate, would ever be exercised under the influence of reason alone.

The sensibilities and motions of the lips and tongue are perfect in the young infant from the beginning. The dread of falling is shewn by the infant long before it could have experience of violence of any kind.

The hand, destined to become the instrument for perfecting the other senses, and for developing the endowments of the mind itself, is, in the infant, absolutely powerless. Pain is poetically figured as the power into whose "iron grasp" we are consigned when introduced to a material world. Now, although the infant is capable of expressing pain in a manner not to be misunderstood, yet it is unconscious of the part of the body which is injured. There occur certain congenital imperfections which require surgical assistance in early childhood; but the infant will make no direct effort with its hand to repel the instrument, or disturb the dressing, as it will do at a period somewhat later.

The lips and tongue are the parts first exercised by the child; the next motion is to put its hand to the mouth, to suck it: and, as soon as the fingers are capable of grasping, whatever they hold is carried to the mouth. Hence the sensibility to touch and power of action in the lips and tongue, are the first inlets to knowledge. The use of the hand is a later acquirement.

The knowledge of external objects cannot be acquired, until the organ of touch has become familiar with our own body. We cannot be supposed capable of judging of the form or tan-

gible qualities of anything in contact with the skin, or of exploring it by the motion of the hand, before having the consciousness of our own body, as distinguished from things external.

The first office of the hand, then, is to exercise the sensibility of the mouth: and the infant as certainly questions the reality of things by that test, as does the dog by its acute sense of smelling. In the infant, the sense of the lips and tongue is resigned in favour of that of vision only when the exercise of the eye has improved, and offers greater attraction. The hand very slowly acquires the sense of touch; and many ineffectual efforts may be observed in the arms and fingers of the child, before it can estimate the direction or distance of objects. Gradually the length of the arm, and the extent of its motions, become the measure of distance, of form, of relation, and perhaps of time.

Next in importance to the sensibility of the mouth, we may consider that sense which is early exhibited in the infant—the terror of falling. The nurse will tell us that the infant lies composed in her arms, while she carries it up stairs; but that it is agitated when she carries it down. If an infant be laid upon the arms and dandled up and down, its body and limbs will be at rest as it is raised; but in descending, it will struggle and make efforts. Here is the indication of a sense, an innate feeling, of danger; and we may perceive its influence, when the child first attempts to stand or run. When set upon its feet, the nurse's arms forming a hoop around it, without touching it, the child slowly learns to balance itself and stand, but under a considerable apprehension; it will only try to stand at such a distance from the nurse's knee, that if it should fall, it can throw itself for protection into her lap. In these, its first attempts to use its muscular frame, it is directed by a fear which cannot as yet be attributed to experience. By degrees it acquires the knowledge of the measure of its arm, the relative distance to which it can reach, and the power of its muscles. Children are, therefore, cowardly by instinct: they show an apprehension of falling; and we may trace the gradual efforts which they make, under the guidance of this sense of danger, to perfect the muscular sense. We thus perceive how instinct and reason are combined in early infancy; how necessary the first is to exist-

ence: how it soon becomes subservient to reason: and how it eventually yields to the progress of reason, until obscured so much, that we can hardly discern its influence.

When, treating of the senses generally, and showing how one organ profits by the other, and how each is indebted to that of touch, I observed, that touch itself is dependent on the exercise of a distinct property—that without the accompaniment of muscular action, and a consciousness of effort, this sense could hardly be an inlet to knowledge at all.

In my lectures, I have always delivered the same views. I have endeavoured to prove that for the perfect exercise of the sense of touch, motion of the hand and fingers, and consciousness of the action of the muscles in producing such motion, must be combined with the feeling of contact of the object. To that consciousness of exertion, I gave the name "muscular sense;" calling it a sixth sense. Although I questioned the correctness of my opinions, when I perceived that none of the chief authorities in mental philosophy, in treating of the senses, adverted to the knowledge obtained from the action of the muscles, yet I can now refer to authors educated to medicine, who have confirmed my views; it having occurred to them, as to me, that the combination of two kinds of sense was required in the organ of touch.

Those distinctions were connected with my inquiries into the functions of the Nervous system. It was the conviction that we are sensible of the action of the muscles which led me to investigate their nerves; first, by anatomy, and then by experiment. I was finally enabled to show, that the muscles are provided with two classes of nerves; that on exciting one of these, the muscle contracts; on exciting the other, no action takes place; and that the nerve which has no direct power over the muscle, is for giving sensation. Thus it was proved, that muscles are connected with the brain, through a "nervous circle;" that one nerve is not capable of transmitting what may be called nervous influence, in two different directions at once; in other words, that a nerve cannot carry volition to the muscles, and sensation towards the brain, simultaneously and by itself: but that, for the regulation of muscular action, two distinct nerves are required; first, a nerve of sensibility to convey a consciousness of the condition of the muscles to the sensorium; and

secondly, a nerve of motion for conveying a mandate of the will to the muscles.

In their distribution through the body, the nervous fibrils which possess these two distinct powers, of conferring sensation, and of exciting the muscles to contraction, are wrapped up, or woven together in the same sheath, and present the appearance of a single nerve: but by examining them where they arise from the brain or spinal marrow, they are found to come off from different tracts, by two distinct "roots;" and the fibrils of these roots soon coalesce, to form what, in reality, are compound nerves, although they appear simple. By anatomical reasoning and experiment I succeeded in demonstrating that one of these roots, with its prolonged fibrils in the nerve, is for bestowing motive power on the muscles; and that the other root, with its prolonged fibrils, is for conferring sensation.*

The Abbé Nollet, after extolling the sense of touch as superior to all the rest, and deserving to be considered the *genus*, under which the others should be included as subordinate *species*, makes this remark—"Besides, it has this advantage over them, to be at the same time both active and passive: for it not only puts it in our power to judge of what makes an impression upon us, but likewise of what resists our impulsions." The mistake here is the same as that to which I have already referred; where it was alleged that the peculiarity of the sense of touch consisted in there being an effort propagated towards it, as well as a sensation received from it. The confusion is obviously from considering the muscular action directed by the will in the exercise of touch, as belonging to the nerve of touch properly. I proceed to show how the sense of motion and that of contact are necessarily combined.

When a blind man, or a man blindfolded, stands upright, neither leaning upon, nor touching aught; by what means does he maintain the erect position? The symmetry of his body is not the cause. A statue of the finest proportion must be soldered to its pedestal, else the wind will cast it down. How is it, then, that a man sustains the perpendicular posture, or inclines in due degree towards the wind that blows upon him? It is obvious that he has a sense by which he knows the inclina-

* See the Account of the Author's Discoveries in the Nervous System, at the commencement of the volume. —(S.)

tion of his body; and that he has a ready aptitude to adjust the parts of it, so as to correct any deviation from the perpendicular. What sense is this? he touches nothing and sees nothing; there is no organ of sense hitherto observed which can aid him. Is it not that sense which we have seen exhibited so early in the infant, in the fear of falling; and which caused its struggles, while it yet lay in the nurse's arms? It can only be by the adjustment of muscles, that the limbs are stiffened, the body firmly balanced, and kept erect; and there is no other source of knowledge but a sense of the degree of exertion in his muscular frame, by which a man can become conscious of the position of his body, and action of his limbs, while he has no point of vision, or the contact of any external body to direct his efforts. In truth, we stand by so fine an exercise of this power, and the muscles, from habit, are directed with so much precision, and with an effort so slight, that we do not know how we stand. But if we attempt to walk on a narrow ledge, or rest in a situation where we are in danger of falling, or balance on one foot, we become subject to apprehension: and the actions of the muscles are then, as it were, magnified, and demonstrative of the degree in which they are excited.

Although we touch nothing and see nothing, yet we are sensible of the position of our limbs; that the arms hang by the sides, or that they are raised and held out. And it must be by a property internal to the frame, that we know this. At one time I entertained a doubt whether this knowledge proceeded from a sense of the condition of the muscles, or from a consciousness of the degree of effort which had been directed to them in volition. But I reasoned in this manner,—we awake with the knowledge of the position of our limbs: this cannot be from a recollection of the action which placed them where they are; it must therefore be a consciousness of their present condition. When a person just after awaking moves his body, it is with a determined object; and before he can desire a change or direct a movement, he must be conscious of a previous condition.

After a limb has been removed by the surgeon, the person still feels pain, and heat, and cold, as if present in the limb. Urging a patient who had lost his leg, to move it, I have seen him catch at the limb, to guard it, forgetting that it was re-

moved. Long after his loss, he experiences a sensation not only as if the limb remained, but as if it were placed or hanging in a particular position or posture. I have asked a patient—"Where do you feel your arm now?" and he has said, "I feel it as if it lay across my breast," or that it is "lying by my side." It seems also to change with the change of posture of the body. These are additional proofs of a muscular sense; that there is an internal sensibility corresponding to the changing condition of the muscles; and that as the sensations of an organ of sense remain, after the destruction of the outward organ, so a deceptious sensibility to the condition of the muscles, as well as to the condition of the skin, will be felt after the removal of a limb.

By such arguments, I have been in the habit of showing that we possess a muscular sense; and that without a perception of the condition of the muscles previous to the exercise of the will, we could not command them in standing, far less in walking, leaping, or running. And as for the hand, it is not more the freedom of its action which constitutes its perfection, than the knowledge which we have of these motions, and our consequent ability to direct it with the utmost precision.*

The necessity for the combination of two distinct properties of the nervous system in the sense of touch, becomes more obvious if we examine their operation in other, but analogous organs; for example, in the palpi or tentacula of the lower animals. These instruments consist of a rigid tube, containing a pulpy matter, in which there is a branch of a nerve that possesses, in an exquisite degree, the sense of touch; and the animals use them for groping their way. When the tentaculum touches a body, and the vibration runs along the pulp of the nerve, the animal can be sensible only of an obstruction; but how is the creature's progress to be directed to avoid it?

* When, on his return home from his wanderings, Ulysses desired to punish the insolence of the beggar Irus, by inflicting on him a severe blow, yet feared lest the well-known power of his arm, if he put forth its whole strength, might betray him to Penelope's suitors, he deliberated on the amount of force he would employ with his fist—

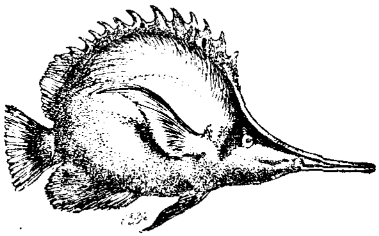
"Whether to strike him lifeless to the earth
At once, or fell him with a measured blow;"

and decided to deal one which would only fracture the beggar's jaw. It must have been a fine calculation that he made, by his muscular sense, of the exertion of the muscles of the arm called for, as well as of the direction of their action, before he delivered the measured blow.

When we see the instrument moving about and feeling on all sides, we must acknowledge that it is the sense of the action of the muscles communicating that motion, which conveys the knowledge of the place or direction of the obstructing body. It appears, therefore, that even in the very lowest creatures, the sense of touch implies the comparison of two distinct senses.

That insects possess the most exquisite organs of sense, must be allowed: but we do not reflect on the extraordinary accuracy with which they measure distances in their movements. This they can only accomplish by an adaptation of the muscular exertion to the sense of vision. The spider, to which I have already alluded—the *aranea scenica*—when about to leap, elevates itself on its fore-legs, and lifting its head, seems to survey the spot before it jumps; if it spy a small gnat or fly on the wall, it creeps very gently towards it, with short steps, till it comes within a proper distance, and then springs suddenly upon it like a tiger. It will jump two feet to seize upon a bee.*

We have a more curious instance of the precision of the eye and of the adaptation of muscular action, in some of the chætodons, as the *chelmon rostratus.*† This fish inhabits the Indian rivers, and lives on the smaller aquatic flies. If it observe one of these insects, alighted on a twig, or flying near, (for it can shoot them on the wing,) it darts forth a drop of water from its beak, with so steady an aim, as to bring the fly into



the water, when it falls an easy prey. These fishes are kept in large vases for amusement; and if a fly be presented on the end of a twig, they will shoot at it with surprising accuracy. In its natural state it will hit a fly at the distance of from three to six inches.

* Kirby.

† Chætodon, a genus of the Acanthopterygii.

The *zeus insidiator** has also the same power of forming its mouth into a tube, and squirting at flies, so as to encumber their wings and bring them to the surface of the water. Now, whether we regard these habits in the lower creatures, as bestowed by instinct, or look upon similar powers belonging to ourselves, as acquired properties, we must acknowledge that in both the operation is compound.†

Some would have us believe that the effect of the impression of odours on the nerve of smelling, is exactly similar to that of light on the nerve of vision; and yet they suppose that the impression on the retina alone suffices to inform us of the direction and distance of objects. But of the direction and distance from which odours come, we are quite ignorant until, by turning the head, and directing the nostrils this way and that, we make a comparison, and at length discover on which side the smell is strongest on the sense.

In insects, the motion of the body is rendered subservient to smell, as well as to vision. There is nothing in the mere exercise of the organ of smell that can direct an insect in its flight: yet, if a piece of carrion be thrown out, flies will approach it,—not by flying in a direct line to it, but by coming towards it in circles. So it is with the bees, in a garden, when attracted to a flower: they may be seen, at first, flying wide, describing circles in their flight, each circle diminishing as they come nearer, until at last they alight upon the object. Having no organ like lungs and thorax to enable them to inhale the effluvia, they make currents in the air, by their mode of flight, so as to impress the nerve of smelling: and it is from the sense of the odour being more acute in one part of the circle, that the next wheel is made; and thus they are directed in a line drawn through these circles, to the flower.

We can judge of the direction from which sounds proceed, without turning the ear towards them. That is because the strength of the vibration is unequal on the two sides of the head; and we can readily compare the two impressions, so as to decide upon the direction. But when a person is deaf in

* Belonging to another genus of the same section.

† A difficulty will occur, to the reader: since the rays of light are refracted at the surface of the water, how does the fish judge of position? Does instinct enable it to do so, or is it experience?

one ear, the comparison is difficult, and he is often mistaken as to the point from which the sound comes; he has more frequent occasion to turn the head, and test the position of the tube of the ear with the strength of the impressions. Accordingly, in mixed company, where there are many speakers, a man in this condition appears positively deaf, from the impossibility of distinguishing minutely the direction of sounds.

The last proof of the necessity of the combination of the muscular sense with the sense of contact will be conclusive. It is not a solitary instance:—A mother while nursing her infant was seized with a paralysis, attended with the loss of muscular power on one side of her body, and the loss of sensibility on the other. The surprising, and indeed the alarming circumstance here was, that she could hold her child to her bosom with the arm which retained muscular power, only so long as she looked to the infant. If surrounding objects withdrew her attention from the state of her arm, the flexor muscles gradually relaxed, and the child was in danger of falling. The details of the case do not belong to our present inquiry; but we see, first, that two distinct properties are possessed by the nerves of the arm, as evinced by the loss of the one, and continuance of the other; secondly, that these two properties exist through different endowments of the nervous system; and, thirdly, that muscular power is insufficient for the exercise of the limbs, without a sensibility to accompany and direct it.

Let me offer another example:—Nothing serves better to make us appreciate the blessings which we enjoy, than examining the organisation of a part which, from its familiarity, and the absolute perfection of its action, we neglect or think meanly of. The lips receive the food, and aid in mastication; they are a principal part of the organ of speech; they are expressive of emotion; they are the most acutely sensible to touch. The vermilion surfaces of the lips possess their exquisite sensibility through minute and delicate villi, into which the extremities of the sensitive nerve are distributed: and these, being covered only with a cuticle the most thin and transparent, afford the ready instrument of touch. Again, a concourse of fine muscles converges to the lips, and surrounds them; and these muscles receive their motor influence from a distinct nerve, coming from

a different quarter of the brain from the sensitive. Now, if this nerve of motion be cut and lose its function, the animal puts its lips to the grains it feeds upon, but cannot gather them. So also, if the nerve of sensation be injured, the animal presses its lips to the food, but wanting the sensibility by which the motion of the lips should be directed, it does not gather them. These facts show that whilst sensibility and motion depend upon different nerves, they are necessarily combined for so simple an act as taking the food into the mouth. As connected with the subject, it is a strange thing to see a person who has every capacity for motion in the lips and tongue, letting the morsel remain in his mouth for hours, without knowing it. The first instance I found of a defect in the lips exactly similar to that produced by the experiment of cutting the nerve of sensation on one side of the face, was in a gentleman who, being under the hands of his dentist, had the nerve of sensation hurt by the pulling of a tooth: having a glass of water given to him, he remarked that the glass was a broken one! The fact being, that the portion of the tumbler in contact with one half of his lips was not felt at all, which gave him the same sensation as if a bit of the glass had been broken away.

The capacity, therefore, of the hand to ascertain the distance, size, weight, *form*, *hardness* or *softness*, *roughness* or *smoothness* of objects, results from its having a compound function—from the sensibility of the proper organ of touch, being combined with the consciousness of the motion of the arm, hand, and fingers.

But it is the motion of the fingers that is especially necessary to the sense of touch. These bend, or extend, or expand, or move in every direction, like palpi, with the advantage of embracing the object, feeling it on all its sides, estimating its solidity or its resistance when grasped, moving round it, and gliding over its surfaces, so as to feel every asperity, and be sensible of every slight vibration.

THE PLEASURES ARISING FROM THE MUSCULAR SENSE.

As much of the knowledge usually supposed to be obtained through the organs of the senses, has its source in the exercise of the muscular frame, so we may trace to it some of our chief enjoyments. It may, indeed, be affirmed that nature benevo-

lently intends that the vigorous circulation of the blood, and healthful condition both of mind and body, should result from alternations of muscular exertion and repose. The pleasure which proceeds from activity, may be partly due to a gratification naturally arising from the exercise of any kind of power—as that implied by mere dexterity, or the successful pursuit of some field sport, or the accomplishment of a work of art. But independently of such sources of satisfaction, active exercise is followed by weariness, and a desire for rest; and although this condition may not be attended with any describable local pleasure, yet after fatigue, and whilst the active powers are sinking into repose, there is diffused through every part of the frame a feeling almost voluptuous. To this feeling an impatience of rest succeeds. Thus are we urged to follow the alternations of activity and of repose necessary to health; and are invited on from stage to stage of our existence.

We owe other enjoyments to the muscular sense. In modern times comparatively little may be thought of the gratifications arising from motion. Yet we read that the gravest of the Greeks, even of the Romans, studied elegance in their attitudes and movements. Their apparel favoured that display of grace, while their exercises and games contributed to encourage elegance of movement. The dances they performed were not exhibitions of mere exuberance of spirits and activity. It was their pride to combine harmony in the motion of the body and limbs, with majesty of gait; their movements consisted more of the unfolding of the arms, than of the play of the feet,—"their arms sublime, that floated on the air." The Pyrrhic dances were attitudes of combat, or martial movements, performed in correct coincidence with the expression of the music. The spectators, in their theatres, must have had very different associations from ours, to account for the national enthusiasm displayed by the influence of their music, and the rage excited by a mere error in time.

This may remind us that in music the divisions of time depend in some degree on the muscular sense. A man will put down his staff in regulated time; and in his common walk, the sound of his steps will fall into a measure. A boy striking the railing in mere wantonness, will do it with a regular succession of blows. This tendency of the muscular frame to

move in accordance with time, is the source of much that is pleasing in music, and assists the effect of melody.

> "The hand
> Sang with the voice, and this the argument."

The closest connection is thus established between the enjoyments of the sense of hearing, and the exercise of the muscular sense.*

The effect of disorders of the nervous system upon the muscular frame, is sometimes to show how natural certain combinations of actions may be, although morbidly excited. The following is a curious illustration :—A young woman, who could not be taught to go down a country-dance, suffering under a nervous illness, began to execute involuntary movements, not unbecoming an opera-dancer. At one time she would pace slowly round the room, with a measured step, the arms carried with elegance, as in a minuet; again, she would stand on the toes of one foot, and beat time with the other; on some occasions she would strike the table, or whatever she could reach, with her hand, many times softly, and then with force; at length it was found that she did everything in rhythm. A friend thought that in her regular beating he could recognise a tune; and he began singing it. The moment the sound struck her ears, she turned suddenly to the man, danced directly up to him, and continued to dance, until he was quite out of breath. The cure of this young woman was of a very unusual kind: a drum and fife were procured, and when a tune corresponding to the rhythm of her movements was played, in whatever part of the room she might be, she would dance close up to the drum, and continue dancing until she missed the step,—when these invo-

* It is probable that we must ascribe to this the power possessed by music over the passions, and even over disease. It is recorded that the music teacher of Socrates [and many will be pleased to know that so sage a man had a music teacher] seeing one inflamed with wine, intent, while the flute was played in Phrygian measure, on setting fire to the house, cured him by ordering the player to change the mode to the grave and soothing Spondæus! Galen records instances of the restorative influence of music over the passions and over disease. And it appears to have been resorted to by Egyptians, Hebrews, Greeks, and Romans, both in acute and chronic disorders. Hence the phrase, "Loca dolentia incantare."

To learn how much of the pleasure of the sense of Vision depends on muscular action, see the "Additional Illustrations" in the Appendix.

luntary motions instantly ceased, and the paroxysm ended. The physician, profiting by this, and observing a motion in her lips, put his ear close to her mouth; he thought he could hear her sing; and questioning her, she said there was a tune continually dwelling upon her ear, which at times irresistibly impelled her to begin her involuntary dance. In the end, she was cured by altering the time, in beating the drum; for, whenever she missed the time, the influence ceased to have its effect.*

If asked what this extraordinary disease is, we can only answer that, being an excitable state of the nervous and muscular systems, it will be called *Chorea;* but it is an instance of a natural combination of muscular actions, morbidly produced; just as in hysteria, where the expression of various natural passions, for example, weeping or laughing, is frequently exhibited.

* Med. Chir. Trans., vol. vii.

CHAPTER X.

THE ORGAN ADAPTED TO THE INSTINCT.—THE HAND NOT THE SOURCE OF INGENUITY OR CONTRIVANCE, NOR CONSEQUENTLY OF MAN'S SUPERIORITY.

SEEING the perfection of the human Hand, both in structure and endowments, we can hardly be surprised at some philosophers entertaining the opinion of Anaxagoras, that the superiority of man is owing to his hand. Although the system of bones, muscles, and nerves belonging to this extremity, is suited to every form and condition of vertebrated animals, yet it is in the human hand that we perceive the consummation of all perfection, as an instrument. This superiority consists in its combination of strength, with variety, extent, and rapidity of motion; in the power of the thumb, and the forms, relations, and sensibility of the fingers, which adapt it for holding, pulling, spinning, weaving, and constructing; properties which may be found separately in other animals, but are combined in the human hand.

In virtue of these provisions, the hand corresponds to the superior mental capacities with which man is endowed. The instrument is capable of executing whatever his ingenuity suggests. Nevertheless, the possession of the ready implement is not the cause of man's superiority: nor is its aptness for execution the measure of his attainments. So we rather say, with Galen, that man has a hand, because he is the wisest of creatures, than ascribe to his possession of a hand, his superiority in knowledge.*

This question has been raised, from observing the perfect

* Ita quidem sapientissimum animalium est homo: ita autem et manus sunt organa sapienti animali convenientia. Non enim quia manus habuit propterea est sapientissimum, ut Anaxagoras dicebat: sed quia sapientissimum erat, propter hoc manus habuit, ut rectissime censuit Aristoteles. Non enim manus ipsæ homines artes docuerunt, sed ratio. Manus autem ipsæ sunt artium organa: sicut lyra, musici; et forceps, fabri.

correspondence between the propensities of animals, and their forms and outward organisation. When we see the heron, still as a grey stone, and hardly distinguishable from it, standing by the water side, intently watching his prey, we might at first suppose this was a habit acquired from the use of his stilt-like limbs, constructed for wading, with his long bill, and flexible neck; for the neck and bill are as much suited to its mode of seizing the fish, as the liester is to the fisherman, in spearing the salmon. But in the configuration of the black bear, there is nothing peculiarly adapted for his catching fish; yet will he sit, on his hinder extremities, by the side of a stream, morning, or evening, on the watch, like a practised fisher; and so perfectly motionless is he, that he will deceive the eye of the Indian, who mistakes him for the burnt trunk of a tree; when the bear sees his opportunity favourable, he will thrust out his fore-paw, and with incredible celerity seize a fish. In this instance, the exterior organ is not the cause of the habit or of the propensity. Hence if we see the instinct bestowed without the appropriate organ, may we not in other examples when the two are conjoined, believe that the habit exists with the instrument, not through it?

The canine teeth are not given without a carnivorous appetite; nor is the necessity of living by carnage joined to a timid disposition; but boldness and fierceness, as well as cunning, belong to the animal armed with retractile claws and sharp teeth, and which preys on the living.* On the other hand, the propensities of the timid vegetable feeder are not to be attributed to his having mobile, erect ears, or prominent eyes: though his suspiciousness and timidity correspond to these forms. The boldness of the bison or the buffalo may be as great as that of the lion; but the impulse that directs them in their mode of attack is different: instinct impels them to gore with their horns. And they will strike with their heads, whether they have horns or not; "The young calf will butt against you before he has horns," says Galen; or as the Scotch song has it, "the putting cow is aye a doddy;" that is, the humble cow (*inermis*), although wanting horns, is ever the most mischievous.

* In some of the quadrumana, the canine teeth are as long and sharp as those of the tiger—but they are instruments of defence only: they bear no relation to the appetite, mode of digestion, or internal organisation.

When that noble animal, the Brahmin bull, of the Zoological Gardens, first put his hoof on the sod, and smelt the fresh grass after his voyage,—placid and easily managed before, he became excited, plunged, and struck his horns into the earth, ploughing up the ground on alternate sides, with a very remarkable precision. This was his dangerous play: just as the dog, in his gambols, worries and fights; or the cat, though pleased, puts out its claws. It would, indeed, be strange, where all else is perfect, if the instinctive character or disposition of the animal were at variance with its arms or instruments.

But the idea may still be entertained, that the accidental use of the organ may conduce to its more frequent exercise, and thereby *to the production of a corresponding disposition*. Such an hypothesis would not explain the facts. The late Sir Joseph Banks, in his evening conversations, told us that he had seen, what many perhaps have seen, a chicken catch at a fly, whilst the shell stuck to its tail. Sir Humphry Davy relates that a friend of his, having discovered, under the burning sand of Ceylon, the eggs of an alligator, had the curiosity to break one of them; when a young alligator came forth, perfect in its motions and in its passions; for although hatched in the sand under the influence of the sunbeams, it made towards the water, its proper element: when hindered, it assumed a threatening aspect, and bit the stick presented to it. We may therefore conclude, that as animals have propensities implanted in them to perform certain motions to which their external organs are subservient, so their passions or dispositions are given as the means of directing them how to defend themselves, or obtain their food.

But this has been well said seventeen hundred years ago. "Take," says Galen, "three eggs, one of an eagle, another of a goose, and a third of a viper: and place them favourably for hatching. When the shells are broken, the eaglet and the gosling will attempt to fly; while the young of the viper will coil and twist along the ground. If the experiment be protracted to a later period, the eagle will soar to the highest regions of the air, the goose betake itself to the marshy pool, and the viper will bury itself in the ground."

We have daily before us proofs of ingenuity in the arts not only surviving the loss of the hand, but excited and exercised,

where the hands were wanting from birth. What is more surprising than to see the feet, in individuals under such circumstances, becoming substitutes for the hands, and working minute and curious things? Unfortunately too, the most diabolical passions will be developed in some natures, and crimes committed which we might have supposed impossible from the power of execution being denied. The most remarkable instance of that was in a man, who from birth was deprived of arms; like the unfortunate youth described in the early part of the volume. As if possessed by a devil, this wretch had committed many murders before being discovered and executed; he was a beggar, who took his stand in the highway some miles from Moscow, on the skirts of a wood: his manner was to throw his head against the stomach of the person who was in the act of giving him charity, and having stunned him, to seize him with his teeth, and so drag him into the wood!

But to turn to a more agreeable topic. The possession of an instrument like the hand, implies that a great part of the organisation which strictly belongs to it, must be concealed. The hand is not a thing appended, or put on, to the body, like an additional movement in a watch; but a thousand intricate relations must be established throughout the whole frame, in connection with it: not only must appropriate nerves of motion and of sensation, and a part of the brain, having correspondence to these nerves, be supplied, but unless, with all this superadded organisation, a propensity to put it into operation were created, the hand would lie inactive.

Voltaire has said, that Newton, with all his science, knew not how his arm moved; so true is it that all such studies have their limits! But, as he acknowledges, a wide difference exists between the ignorance of the child or peasant, and the consciousness of the philosopher that he has arrived at a point of knowledge beyond which man's faculties do not carry him.

Nevertheless, is it *nothing to have our minds awakened to* the perception of the numerous proofs of design which present themselves in the study of the Hand—to be brought to the conviction that everything in its structure is orderly and systematic, and that the most perfect mechanism, the most minute and curious apparatus, and sensibilities the most delicate and appropriate, are all combined in operation that we may move the

hand? What the first impulse to motion is, or how the mind is related to the body, we know not; yet it is important to learn with what extraordinary contrivance, and perfection of workmanship, the bodily apparatus is placed between that internal faculty which impels us to use it, and the exterior world.

I have been asked, and that by men of the first education and talents, whether in the organs of voice of the orang-outang anything really deficient had been discovered to prevent him from speaking. The reader will give me leave to place the matter correctly before him. In speaking, there is, first, a certain force of expired air, or an action of the whole muscles of respiration required; in the second place, the vocal chords at the top of the wind-pipe must be drawn by their muscles into accordance, else no vibration will take place, and no sound issue; thirdly, the open passages of the throat must be expanded, contracted, or extended, by their numerous muscles, in correspondence with the condition of the vocal chords; and these must all sympathise, before even a simple sound will be produced. But to articulate that sound, so that it may become part of a conventional language, there must be added actions of the pharynx, of the palate, of the tongue, and of the lips. The exquisite organisation for all this, is not visible in the organs of the voice, as they are called: it is to be found in the nerves, which combine these various parts in one simultaneous act. The meshes of a spider's web, or cordage of a man-of-war, are few and simple, compared with the concealed filaments of nerves which move these parts; and if but one of them be wanting, or its tone or action disturbed in the slightest degree, everybody knows how a man will stand with his mouth open, twisting his tongue and lips in vain attempts to utter a word.

It will now appear that there must be distinct lines of association, suited to the organs of voice: different to combine them in the bark of a dog, in the neighing of a horse, or in the shrill whistle of the ape. That wide distinctions exist in the structure of the vocal organs in different classes of animals, is most certain; but independently of those which are apparent, there are secret and minute varieties in the associating nervous cords. The ape, therefore, does not articulate—first, because the organs are not perfect to that end; secondly, because the

nerves do not associate the different parts of the organ in that harmony of action which is necessary to speech; and, lastly, were all the exterior apparatus perfect, there is no impulse to the act of speaking.

From this enumeration of parts it will appear that the main difference lies in the internal faculty or propensity. As soon as a child can distinguish and admire, then are its features in action; its voice begins to be modified into a variety of sounds; these are taken up and repeated by the nurse, and already a sort of convention is established between them. The perfect correspondence between the vocal instrument, and the laws governing the motions of the air, is a contrivance; but that which prompts to the first efforts at articulation, is in our intellectual nature. We cannot, therefore, doubt that a propensity is created in correspondence with the outward organs, and without which these outward organs would be useless appendages. The aptness of the instrument and its exercise will undoubtedly improve the faculty—just as we find that giving freedom to the expression of passion, adds force to the emotion in the mind.

One cannot but reflect here on that grand revolution which took place when language, till then limited to its proper organ, had its representation in the work of the Hand. Now that a man of mean estate may possess a library of more intrinsic value than that of Cicero, when the sentiments of past ages may be as familiar to him as those of the present, and when the knowledge of different empires is transmitted and common to all, we cannot expect our sages to be followed, as of old, by their five thousand scholars. Nations will not now record public acts by building pyramids, consecrating temples, or raising statues, once the only means of perpetuating great deeds or extraordinary virtues. It is in vain that our artists complain of patronage being withheld. The ingenuity of the Hand has at length subdued the arts of design. Printing has made all other records barbarous; and great men build for themselves a "livelong monument."

On this, as upon many other occasions, it may be urged that a further multiplication of evidences in favour of natural religion is unnecessary; it may be said that we only vary the instances, without making the proofs stronger. For example,

as to speech, no higher argument can be sought for to prove the perfection of design, than the simple fact that, by means of the voice, two intellectual beings can breathe out their thoughts, and hold communion on the ideas that arise in their minds: the knowledge of the intricate organs by which voice is produced, can add nothing to our wonder, or to the force of our conviction, that all which regards man's state is ordered in perfection. So, philosophically considered, our admiration ought to be as great from observing that by willing it, we can raise the arm, as from knowing all the relations of the nerves, muscles, bones, and joints of the arm, through which that motion is accomplished. But I would ask, who, in speaking or moving his arm, thinks of these proofs of design, or feels this emotion? Do these actions excite either admiration or gratitude? Before such feelings arise, do we not require to be brought to consider them anew? Is it not agreeable to know how such actions are performed? Is it not important, therefore, that the emotions of surprise and gratitude excited by contemplating them, should be repeated and enforced, until they become an enduring devotional feeling? In fine, whilst it is pleasing to reflect that the great authorities in natural science, in times past, have entertained the belief of the great Architect, and of the continuance of His government, it cannot be without its use to add strength to the same belief, by having recourse to those improvements which in all departments of knowledge are being daily introduced.

OF EXPRESSION IN THE HAND.—Before we conclude, let us speak of the Hand as an organ of Expression. Formal dissertations have been composed on this topic. But were we to seek for authorities, we should take in evidence the works of the great Painters. By representing the hands disposed in conformity with the attitude of the figures, the old masters have been able to express every different kind of sentiment in their compositions. Who, for example, has not been sensible to the expression of reverence in the hands of the Magdalens by Guido, to the eloquence of those in the cartoons of Raphael, or the significant force in those of the Last Supper, by Da Vinci? In these great works may be seen all that Quintilian says the hand is capable of expressing:—"For other parts of the body assist the speaker, but these, I may say, speak them-

selves. By them we ask, we promise, we invoke, we dismiss, we threaten, we entreat, we deprecate, we express fear, joy, grief, our doubts, our assent, our penitence; we show moderation, profusion; we mark number and time."*

Buffon has attempted to convey to us, how knowledge may have been originally imparted in the world, by fancifully tracing the impressions on the newly awakened senses of the First created Man. But, for that which in our great Poet is both consistent and splendid—imagining man to raise his wondering eyes to heaven, and spring, by quick instinctive motion, as "thitherward endeavouring,"—Buffon substitutes a poor combination of philosophy with false eloquence.

For greater dramatic effect, the first created man is supposed to address us himself; and he commences thus:—"he remembers the moment of his creation—that time, so full of joy and trouble, when first he looked around on the verdant lawns and crystal fountains, and beheld the vault of heaven over his head!" He then proceeds to declare,—"that he knew not what he was, or whence he came, but believed that all he saw was part of himself." Thus he is represented as conscious of objects, which even to see implies experience, and to enjoy supposes a thousand agreeable associations already formed. But he goes on to say, from that blissful state he is awakened "by striking his head against a palm-tree, which he had not yet learned could hurt him!"

Men are often diffident of their first acquired knowledge, and conceive that philosophy must lead to something very different from what they have been early taught. Hence, perhaps, the absurdity of this attempt to unite philosophy and poetry.

Later writers have argued that we have no grounds for supposing that there has been, at any time, an interruption to the uniform course of nature; meaning by the term, uniformity of nature, the prevalence of the same laws which are now in operation. If it were found, they say, that on the arrival of a colony in a new country, fruits were produced spontaneously around

* "Nam ceteræ partes loquentem adjuvant, hæ, prope est ut dicam, ipsæ loquuntur. His poscimur, pollicemur, vocamus, dimittimus, minamur, supplicamus, abominamur, timemus; gaudium, tristitiam, dubitationem, confessionem, penitentiam, modum, copiam, numerum, tempus, ostendimus," &c.

them, and flowers sprung up under their feet, then, we might suppose that our first parents were placed in a scene of profusion and beauty—suited to their helpless condition—and unlike what we see now in the course of nature. It is not very wise to entertain the subject at all; but if it is to be discussed, this is starting altogether wide of the question. We do not desire to know how a whole tribe migrating westward, could find sustenance,—but in what state man could be created and live, without a deviation from what is called the uniform course of nature. If the first man had been formed helpless as an infant, he must have perished: and if mature in body, he must have been gifted with faculties suited to his condition. A human being, pure from the Maker's hands, with desires and passions implanted in him adapted to his state, and with a suitable theatre of existence, implies something very near what we have been early taught to believe.

In every change which the globe has undergone, an established relation is perceived between the animal that has been created, and the elements around it. It is idle to suppose that this has been a matter of chance. Either the structure and functions of the animal must have been formed to correspond to the condition of the elements, or the elements must have been controlled to minister to the necessities of the animal; and if, in contemplating all the inferior gradations of animal existence, the most careful investigation leads us to this conclusion, what makes us so unwilling to admit such an influence, in the last grand work of creation, the introduction of man?

We cannot resist these proofs of a beginning, or of a First Cause. When we are bold enough to extend our inquiries into those great revolutions that have taken place, whether in the condition of the earth, or in the structure of the animals which have inhabited it, our notions of the "uniformity" of the course of nature must suffer some modification. At certain epochs, changes in the face of the globe have been wrought, and beings differing from those previously, or now existing, must have been brought into existence. Such interference is not contrary to the great scheme of creation; it is so only to our present state. For the most wise and benevolent purposes, a conviction is implanted in our nature that we may rely on the course of events being permanent. We belong to a certain epoch; and it is when

our ambitious thoughts carry us beyond our natural condition, that we feel how much our faculties are confined, and our conceptions, as well as our language, imperfect. We must either abandon these speculations altogether, or cease to argue purely from our present situation.

It has now been made manifest, that man, and the animals inhabiting the earth, have been created with reference to the magnitude of the globe;—that their living endowments bear a relation to the elements around them. We have also learned that the system of animal bodies, notwithstanding the diversity of forms that meet the eye, is simple and universal: that it not only embraces all living creatures, but has been continued from periods of the greatest antiquity, according to the geological calculations of time. The most obvious appearances, and the labours of the geologist, give us reason to believe that the earth has not always been in the state in which it is now presented to us. Every substance that we see is compound; we nowhere obtain the elements of things: the most solid materials of the globe are formed of decompounded and reunited parts. Changes, therefore, have been wrought on the general surface, with long periods, or epochs, intervening; and the proofs of these are as distinct as the furrows on a field are indicative that the plough has passed over it. In short, progressive changes, from the lowest to the highest state of organisation and of enjoyment, point to the great truth, that there was a beginning.

There is nothing in the inspection of the species of animals, which countenances the idea of a return of the world to any former condition. When we acknowledge that animals have been created in succession and with an increasing complexity of parts, we are not to be understood as admitting that there is here proof of a growing maturity of power, or an increasing effort in the Creator. And for this very plain reason, which we have stated before, that the bestowing of life, or the union of the vital principle with the material body, is a manifestation of power, superior to that displayed in the formation of an organ, or the combination of many organs, or construction of the most complex animal mechanism. It is not, therefore, a greater power that we see in operation; but a power manifesting itself in the perfect and successive adaptation of one thing to another —of vitality and organisation to inorganic matter.

We mark changes in the earth's surface, and observe, at the same time, corresponding changes in the animal creation. We remark varieties, in the outward form, size, and general condition of animals, with corresponding varieties in the internal organisation,—until we find Man created, of undoubted pre-eminence over all, and placed suitably in a bounteous condition of the earth.

There is extreme grandeur in the thought of an anticipating or prospective intelligence: in the reflection that what was finally accomplished in man, was begun in times incalculably remote. Most certainly the original crust of the earth has been fractured and burst up, that its contents might be exposed; that they might be resolved and washed away by the vicissitudes of heat, cold, and rain: mountains and valleys have been formed: the changes of temperature in the atmosphere have ensured continual motion and healthful circulation: the plains have been made salubrious, and the damps which hung on the low grounds have gathered on the mountains in clouds, so that refreshing showers have brought down the soil to fertilise the plain. In this manner have been supplied the means necessary for man's existence; with objects suited to excite his ingenuity, to reward it, and to develop all the various properties both of his body and of his mind. And thus it is, "that the invisible things, from the creation of the world, are perceived by what we do see."

Nor are these conclusions too vast to be drawn from the examination of a part so small as the Human Hand; since we have shown that the same system of parts which constitutes the perfection of that instrument adapted to our condition, had its type in the members of those vast animals which inhabited the bays and inland lakes of a former world. If we seek to discover the relations of things, how sublime is that established between the state of the earth's surface, which has resulted from a long succession of revolutions, and the final condition of its inhabitants, as created in accordance with these changes!

To our measure of time, nothing is more surprising than the slowness with which the designs of Providence have been fulfilled. But as far as we can penetrate by the light of natural knowledge, the condition of the earth, and with it, Man's destinies, have hitherto been accomplished in great epochs.

We have been engaged in comparing the structure, organs, and capacity of man and of animals. We have traced a relation. But we have also observed a broad line of separation between them—Man alone capable of reason, affection, gratitude, and religion: sensible to the progress of time, conscious of the decay of his strength and faculties, of the loss of friends, and the approach of death.

One who was the idol of his day has recorded his feelings on the loss of his son, in nearly these words:—"We are as well as those can be who have nothing further to hope or fear in this world. We go in and out, but without the sentiments that can create attachment to any spot. We are in a state of quiet, but it is the tranquillity of the grave, in which all that could make life interesting to us is laid." If in such a state there were no refuge for the mind, then were there something wanting in the scheme of nature:—an imperfection in man's condition, at variance with the benevolence which is manifested in all other parts of animated nature.

The extension of knowledge does not always direct the mind to the most consolatory contemplations. We may contrast the ancient philosopher with the modern. The former, viewing everything as suited, or subordinate to man, considered him as a "little god, harboured in a human body," and yielded unresistingly to the sentiments which flowed directly from the objects and phenomena around him.

But as the period advanced when by philosophical inquiry, experiment, and the improvement of optical instruments, vision was extended to objects too remote, or too minute for its natural sphere—when, instead of the wide plane and visible horizon of the stable earth, our globe was thought of as a ball rolling, amidst myriads greater than it, through infinite space; there was a danger that man would consider his own position with different sentiments; that he would fall back with the impression of the littleness of all belonging to him; that his life would seem but a point of time, compared with geological periods; his body as a mere atom driven about amidst unceasing changes of the material world. To him, "the earth, with Man upon it, does not seem much more than an ant-hill, where some ants carry corn, and some carry their young, and some go empty, and all to and fro a little heap of dust."

The danger of adopting such disproportioned views of man's estate, is greater to the scholar than to the philosopher. He who has the power and the genius to investigate nature, will not be satisfied with the discovery of secondary causes; his mind will become enlarged, and his thoughts more elevated. It is otherwise with him who learns, at second-hand, the result of those inquiries. If such an one see the fire of heaven brought down into a phial, or materials compounded to produce an explosion louder than the thunder, and ten times more destructive, the storm will no longer speak an impressive language to him. When, in watching the booming waves of a tempestuous sea along the coast, he marks the line at which the utmost violence of the ocean is stemmed, and by an unseen influence thrown back, he is more disposed to feel the providence extended to man, than when the theory of the moon's action is, as it were, interposed between the scene which he contemplates, and the sentiments naturally arising in his breast. Those influences which are natural and just, and have served to develop the sentiments of millions before him, are dismissed as vulgar and to be despised. With the pride of newly-acquired knowledge, his conceptions embarrass, if they do not mislead him; in short, he has not had that intellectual discipline which should precede and accompany the acquisition of knowledge.

But a man, of the highest order of genius, may lose the just estimate of himself from another cause. The sublime nature of his studies may consign him to depressing thoughts. He may forget the very attributes of his mind, which have privileged these high contemplations, and the ingenuity of the hand, which has so extended the sphere of his observation. The remedy, to such a mind, is in the studies which we are enforcing. The heavenly bodies in their motions through space, are held in their orbits by the continuance of a Power not more wonderful or more to be admired, than that by which a globule of blood is suspended in the mass of fluids—or by which, in due season, it is attracted and resolved; than that by which a molecule entering into the composition of the body, is driven through a circle of revolutions and made to undergo different states of aggregation—becoming sometime, a part of a fluid, sometime an ingredient of a solid, and finally cast out again, from the influence of the living forces.

Our argument, in the early part of the volume, has shown Man, by the power of the Hand, (as the ready instrument of the mind,) accommodated to every condition through which his destinies are to be accomplished. We first see the hand ministering to his necessities, and sustaining the life of the individual. In a second stage of his progress, we see it adapted to the wants of society, when man becomes a labourer and an artificer. In a state still more advanced, science is brought in aid of mechanical ingenuity, and the elements which seemed adverse to the progress of society, become the means conducing to it. The seas, which at first set limits to nations, and grouped mankind into families, are now the means by which they are associated. Philosophical chemistry has subjected the elements to man's use; and all tend to the final accomplishment of the great objects to which everything, from the beginning, has pointed—the multiplication and distribution of mankind, and the enlargement of the sources of man's comfort and enjoyment—the relief from too incessant toil, and the consequent improvement of the higher faculties of his nature. Instinct has directed animals, until they are spread to the utmost verge of their destined places of abode. Man too is borne onwards; and although, on consulting his reason, much is dark and doubtful, yet does his genius operate to fulfil the same design, enlarging the sphere of life and enjoyment.

Whilst we have before us the course of human progress, as in a map, we are recalled to a nearer and more important consideration: for what to us avail all these proofs of Divine power—of harmony in nature—of design—the predestined accommodation of the earth, and the creation of man's frame and faculties, if we are stopped here? if we perceive no more direct relation between the individual and the Creator? But we are not so precluded from advancement. On the contrary, reasons accumulate at every step, for a higher estimate of the living soul, and give us assurance that its condition is the final object and end of all this machinery, and of these successive revolutions.

To this must be referred the weakness of the frame, and its liability to injury, the helplessness of infancy, the infirmities of age, the pains, diseases, distresses, and afflictions of life—for by such means is man to be disciplined—his faculties and virtues unfolded, and his affections drawn to a spiritual Protector.

As every instinct, or sense, has an end, or design; and every emotion in man has its object and direction; we must conclude that the desire of communing with God is but another test of his being destined for a future existence, and the longing after *immortality the promise of it.*

APPENDIX.

ADDITIONAL ILLUSTRATIONS.

[THE MECHANICAL PROPERTIES OF THE SOLID STRUCTURE OF THE ANIMAL BODY CONSIDERED.

To prepare us for perceiving design in the various internal structures of an animal body, we must first of all know that perfect security against accidents is not consistent with the scheme of nature. A liability to pain and injury only proves how entirely the human body is formed with reference to the Mind: since, without the continued call to exertion, which danger and the uncertainty of life infer, the development of our faculties would be imperfect, and the mind would remain, as it were, uneducated.

The contrivances (as we should say of things of art) for protecting the vital organs, are not absolute securities against accidents; but they afford protection in that exact measure or degree calculated to resist the shocks and pressure to which we are exposed, in the common circumstances of life. A man can walk, run, leap, and swim, because the texture of his frame, the strength and power of his limbs, and the specific gravity of his body, are in relation to all around him. But were the atmosphere lighter, the earth larger, or its attraction greater—were he, in short, an inhabitant of another planet, there would be no correspondence between the strength, gravity, and muscular power of his body, and the elements around him; and the balance in the chances of life would be destroyed.

Without such considerations, the reader would fall into the mistake, that weakness and liability to fracture imply imperfection in the frame of the body; whereas a deeper contemplation of the subject will convince him of the incomparable perfection both of the plan and of the execution. The body is intended to be subject to derangement and accident, and to become, in the course of life, more and more fragile, until, by some failure in the framework or vital actions, life terminates.

And this leads us to reflect on the best means of informing ourselves of the intention or design shown in this fabric. Can there be any better mode of raising our admiration than by comparing it with things of human invention? It must be allowed that we shall not find a perfect analogy. If we compare it with the forms of architecture—the house or the bridge is not built for motion, but for solidity and firmness, on the principle of gravitation. The ship rests in equilibrium, prepared for passive motion, and the contrivances of the shipbuilder are designed for resisting an external force. Whereas *in the animal body, we perceive securities against the gravitation* of the parts; provisions to withstand shocks and injuries from without; at the same time that the framework is calculated to sustain an internal impulse from the muscular force, which moves the bones as levers, or, like an hydraulic engine, propels the fluids through the body.

As in things artificially contrived, lightness and motion are balanced against solidity and weight, so it is in the animal body. A house is built on a foundation, immoveable; and the slightest shift of the ground, followed by the ruin of the house, brings no discredit on the builder; for he proceeds on the certainty of strength from gravitation on a fixed foundation. But a ship is built with reference to motion; to receive an impulse from the wind, and to move through the water: in comparison with the fabric founded on the fixed and solid ground, it becomes subjected to new influences, and in proportion as it is fitted to move rapidly in a light breeze, it is exposed to founder in the storm. A log of wood, or a Dutch dogger, almost as solid as a log, is comparatively safe in the trough of the sea during a storm—when a bark, slightly built and fitted for lighter breezes, would be shaken to pieces; that is to say, the

masts and rigging of a ship (the provisions for its motion) may become the source of weakness, and, perhaps, of destruction; and safety is thus voluntarily sacrificed in part, to obtain another property, motion.

So in the animal body: sometimes we see the safety of parts provided for by strength calculated for inert resistance; but when made for motion, when light and easily influenced, they become proportionally weak and exposed; unless some other principle be admitted, and a different kind of security be substituted for that of weight and solidity: still a certain insecurity arises from this delicacy of structure.

We have already had occasion to show that there is always a balance between the power of exertion, and the capability of resistance, in the living body. A horse or a deer receives a shock in alighting from a leap; but still the inert power of resisting that shock, bears a relation to the muscular power with which it springs. And so it is in man; the elasticity and strength of his limbs are always accommodated to his activity. But it is obvious, that in a fall, the shock which the lower extremities are calculated to resist, may come on the upper extremity; which, from being adapted for extensive and rapid motion, is incapable of sustaining the impulse, and the bones are broken or displaced.

The analogy between the structure of the human body and the works of human contrivance, is, therefore, not perfect. Sometimes the material is different, sometimes the end to be attained is not precisely the same; and, above all, in the animal body a double object is often secured by the structure or framework, which cannot be accomplished by mere human ingenuity, and of which, therefore, we can offer no illustration strictly correct. However ingenious our contrivances may be, they are not only limited, but they present a sameness which becomes tiresome. Nature, on the contrary, gives us the same objects of interest, or images of beauty, with such variety, that they lose nothing of their influence and attraction by repetition.

If, from a too careless survey of external nature, and the consequent languor of his reflections, the reader have an imperfect notion of design and providence, we hope that the mere novelty of the instances we have to place before him, may carry con-

viction to his mind; for we draw from nature in a field which has been left strangely neglected, though the nearest to us of all, and of all the most fruitful.

Men proceed in a slow course of advancement in architectural, mechanical, or optical sciences; yet it is found that when an improvement is made, there are all along examples of it in the animal body; which ought to have been marked before, and which might have suggested to us the improvement. It is surprising that this view of the subject has seldom, if ever, been taken seriously, and never pursued. Is the human body formed by an all-perfect Architect, or is it not? And, if the question be answered in the affirmative, does it not approach to something like infatuation, that, possessing such perfect models as we do in the anatomy of the body, we are so prone to neglect them? We undertake to prove that the foundation of the Eddystone lighthouse, the perfection of engineering skill, is not formed on principles so correct as those which have directed the arrangement of the bones of the foot; that the most perfect pillar or kingpost is not adjusted with the accuracy of the hollow bones which support our weight; that the insertion of a ship's mast into the hull is a clumsy contrivance compared with the connexions of the human spine and pelvis; and that the tendons are composed in a manner superior to the last patent cables of Huddart, or the yet more recently improved chain-cables of Bloxam.

In two introductory chapters of his "Natural Theology," Archdeacon Paley has given us the advantage of simple, but forcible language, with extreme ingenuity, in illustrating the mechanism of the frame. But for his example, we should have felt some hesitation in making so close a comparison between design, as exhibited by the Creator in the animal structure, and the mere mechanism, the operose and imperfect contrivances, of human art.

Certainly there may be a comparison; for a superficial and rapid survey of the animal body may convey the notion of an apparatus of levers, pulleys, and ropes, which may be compared with the spring, barrel, and fusee, the wheels and pinions of a watch. But if we study the texture of animal bodies more curiously, and especially if we compare animals with each other

—for instance, the simple structure of the lower creatures with the complicated structure of those higher in the scale of existence—we shall see that, in the lowest links of the chain, animals are so simple, that we should almost call them homogeneous; and yet there, we find life, sensibility, and motion. It is in the animals higher in the scale that we discover parts having distinct endowments, and exhibiting complex mechanical relations. The mechanical contrivances which are so obvious in man, are the provisions for the agency and dominion of an intellectual power over the materials around him.

We mark this early, because there are authors who, looking upon this complexity of mechanism, confound it with the presence of life itself, and think that it is a necessary adjunct—nay, even that life proceeds from it; whereas the mechanism which we have to examine in the animal body, is formed with reference to the necessity of acting upon, or receiving impressions from, things external to the body; an inevitable condition of our state of existence in a material world.

Many have expressed their opinion very boldly on the necessary relation between organisation and life, who have never extended their views to the system of nature. To place man, an intelligent and active being, in this world of matter, he must have properties bearing relation to that matter. The existence of matter implies an agency of certain forces; the particles of bodies must suffer attraction and repulsion, and the bodies formed by the balance of these influences upon their atoms or particles, must have weight or gravity, and possess mechanical properties. So must the living body, independently of its peculiar endowments, have similar composition and qualities, and have certain relations to the solids, fluids, gases, heat, light, electricity, or galvanism, which are around it. Without these, the intellectual principle could receive no impulse—could have no agency and no relation to the material world. The whole body must gravitate or have weight; without which it could neither stand securely nor exert its powers on the bodies around it. But for this, muscular power itself, and all the appliances which are related to that power, would be useless. When, therefore, it is affirmed that organisation or construction is necessary to life, we may at least pause in giving assent, under the certainty that we see another and a different reason for the con-

struction of the body. Thus we perceive, that as the body must have weight to have power, so must it have mechanical contrivance, or arrangement of its parts. As it must have weight, so must it be sustained by a skeleton; and when we examine the bones, which give the body height and shape, we find each column (for in that sense a bone may be first taken) adjusted with the finest adaptation to the perpendicular weight it has to bear, as well as to the lateral thrusts to which it is subject in the motions of the body.

The bones also act as levers, on the most accurate mechanical principles. And whilst these bones are necessary to give firmness and strength to the frame, it is admirable to observe that one bone never touches another; but a fine elastic material, the cartilage, intervenes betwixt their ends, the effect of which is to give a very considerable degree of elasticity to the whole frame. Without such elasticity a jar would reach the more delicate organs, even in the very recesses of the body, at every violent motion; and, but for this provision, every joint would creak by the attrition of the surfaces of the bones. The bones are surrounded by the flesh or muscles. The muscle is a particular fibrous texture, which alone, of all the materials constituting the frame, possesses the peculiar inherent power or endowment of contracting; it is this power which we are to understand when professional men speak of irritability. The contraction of the muscle bears no proportion to the cause which brings it into operation; more than the touch of the spur upon the horse's side does, as a mechanical impetus, to the force with which the animal propels both himself and rider. Each muscle of the body—and by common estimate there are hundreds—is isolated; and no property of motion is propagated from one to another; they are distinct instruments of motion. The muscles surround the bones, and are so beautifully classed, that in every familiar motion of the limbs some hundreds of them are adjusted in their exact degree, to effect the simplest change in the position of the body. Each fibre of a muscle, and a muscle may contain millions of fibres, is so attached to the tendon, that the whole power is concentrated there; and it is the tendons of the muscles which, like ropes, convey the force of the muscles to the bones. The bones are passive levers; the muscles are the active parts of the frame. With all the seeming intricacy

in the running and crossing of these tendons, they are adjusted accurately on mechanical principles. Where it is necessary, they run in sheaths, or they receive new directions by lateral ligamentous attachments, or there are placed under them smooth and lubricated pulleys, over which they run; and where there is much friction, there is a provision equal in effect to the friction-wheel of machinery. Thus the bones are levers, with their heads most curiously carved and articulated; and joined to the intricate relations of the muscles and tendons, they present on the whole a piece of perfect mechanism.

It is with this texture—the coarsest, toughest portion of the animal frame—that a parallel is drawn, when we compare it with the common mechanical contrivances of machinery. But whilst these grosser parts of the living body exhibit a perfection in mechanical adaptation far greater than the utmost ingenuity of man can exhibit in his machinery, let the reader remember that they are surpassed as objects of admiration by the finer organs; such, for example, as the structure of those nerves which carry the mandate of the will to the moving parts; or of the vessels which convey the blood in the circulation, and where the laws of hydraulics may be finely illustrated; or of those secreting glands, where some will affirm the galvanic influence is in operation, with something subtler than the apparatus of plates and troughs. And could we compare the contrivances of man, with such fine mechanisms in the animal frame, there are structures to be adduced, much more admirable still. The organs of the senses, which are so many inlets for the qualities of surrounding matter to excite corresponding sensations and perceptions, afford us delightful subjects of contemplation; and give proofs of design in the human organism the most conclusive, not only in regard to the system of the body itself, but as it forms a part of the great scheme of the universe.]

OF THE SOLID STRUCTURES OF ANIMAL BODIES.

SUBSTITUTES FOR THE TRUE SKELETON.

It has been shown, in the first chapters, that solidity and gravity are qualities necessary to every inhabitant of the earth; the first, to protect it; the second, that the animal may stand, and possess that resistance which shall make the muscles available for action. In all animal bodies, besides those structures on which their economy and much of their vital functions depend, there must be a texture to give firmness. Without this, the vegetable would have no characteristic form; and animals would want the protection necessary for their delicate organs, and could not move upon their extremities. We have to show with what admirable contrivance, in the different classes of organised beings, this firm fabric is reared; sometimes to protect the parts, as a shell; and sometimes to give them form and motion, as in the skeleton.

In vegetables, as in animals, a certain firm material is essential to support the parts which are the living active organs of their system, and which are so beautiful and interesting. The ligneous or woody fibre is a minute, elastic, semi-opaque filament, which, closing in and adhering to other filaments of the same kind, forms the grain or solid part of the wood. The best demonstration of the office of the woody fibre is in the leaf. When the leaf of a plant is prepared by maceration and putrefaction, and the soft part washed away, there remains an elegant skeleton of wood, which retains the form of the leaf, and is perfectly well suited to support its delicate organisation. It is the same substance which, when accumulated and condensed, gives form and strength to the roots and branches of the oak. And these, though fantastic and irregular in their growth, preserve a mechanical principle of strength; as obvious, to the ship-builder, in the knees of timber, as in the delicate skeleton of the leaf: Lord Bacon speaks of "knee-timber that is good for ships that are to be tossed." The woody fibre, though not

directly engaged in the living functions of the tree, is yet essential for extending the branches and leaves to the influence of the atmosphere, and by its elasticity under the pressure of the wind, giving what is equivalent to exercise for the motion of the sap. A tree opposed to winds and to a severe climate is dense in its grain, and the wood is preferred by the workman to that which is the growth of a milder climate.

We cannot miss seeing the analogy of the woody fibre to the bones of animals. Bones are firm, to sustain the animal's weight, and to give it form. They are jointed, and move under the action of muscles; and this exercise promotes the activity of the living parts, and is necessary to health. But let us first observe the structure of some of the lower animals. It will be agreeable to find the hard material, though always appropriate and perfect, becoming more and more mechanical and complex in its construction, from the lithophytes, testacea, crustacea, reptiles, fishes, mammalia, up to Man.

The first material to be taken notice of, which bestows this necessary firmness on the animal textures, is the *cellular substance.* This consists of delicate membranes, which form cells; these cells communicate with each other, and the tissue thus composed enters everywhere into the structure of the animal frame. It constitutes the principal part of the *medusa*, which floats like a bubble on the water; and it is found in every texture of the human body. It forms the most delicate coats of the eye; and gives toughness and firmness to the skin. It is twisted into ligaments, and knits the largest bones: it is the medium between bone, muscle, and blood-vessel: it produces a certain firmness, and union of the various component parts of the body, while it admits of their easy motion. Without it, we should be rigid, notwithstanding the proper organs for motion; and the cavities could not be distended or contracted, nor could the vessels pulsate.

But the cellular texture is not sufficient on all occasions, either for giving strength or protection: nor does it serve to sustain the weight, unless the animal lives suspended in water, or creeps upon the ground. Shell-fish have their strong covering for a double purpose: to keep them at the bottom of the sea, and to protect them when drifted by the tide against rocks. Those animals of the molluscous division which inhabit the

deep sea, and float singly, or in groups, as the genus scalpa, have a leathern covering only; because they are not liable to the rough movements to which the others are subject, in the advancing and retiring tides. The scalpa, simple as it is in structure —for it presents the appearance of a mere bag with two orifices capable of opening and closing by valves—possesses at once all the functions of digestion, respiration, reproduction, and, more strange than any, locomotion; in its outward form and substance, we may see the provisions for its mode of life, and the place that it holds: from floating or swimming at will, it is one of the "natantes;" and it is further distinguished by the term "tunicata," from being furnished with a leathern coat: now it is worthy of admiration, that although unprovided with exterior members, and having only two or three muscular bands attached to its outward covering, it can move from place to place, by merely taking in, and throwing out, the water in which it floats; and the same operation is sufficient to supply it with its food, and carry on the process of respiration.

The hermit crab gives us a demonstration of the necessity for a protecting covering. Its tail or hinder part has no crust or shell upon it, as its body and claws have; therefore this animal requires to seek a suitable dwelling-place for itself—some empty univalve shell, into which it insinuates its tail, and from which its head and arms project: with this power of selecting a house, it removes, when it has outgrown the shell in which it has dwelt; and may then be seen trying the empty shells upon the shore, or contending with others of its own species for the possession of a shell. Surveying these instances, we cannot resist the conviction of the fine adaptation of the sensibilities and instincts of animals to their forms and substances.

With all this, when we look to animals of more complex structure, possessing a distinct system of muscles, we perceive the necessity for some harder and more resisting material being added, if the weight is to rest on points or extremities; or if the muscular activity is to be concentrated. And nature has other means of supplying the fulcrum and lever, besides the bones, or true skeleton, which we have been examining in the first part of the volume. Perhaps we shall find that there is a system of solid parts superior even to what we have been studying in the *vertebrata*.

The larvæ of proper insects, and the annelides, have no exterior members for walking or flying: but to enable them to creep, they must have points of resistance, or their muscles would be useless. Their skins suffice; and these are hardened by a deposit within them, for that purpose. But if this skin were not further provided, it would be rigid and unyielding, and be no substitute for bone. The hardened integuments are, therefore, divided into rings; to these the muscles are attached; and as the cellular membrane between the rings is pliant, the animals are enabled to creep and turn in every direction.

Without further argument, we perceive how the skin, by having a hard matter deposited within it, is adapted to all the purposes of the skeleton. It is worthy of notice that some animals, still lower in the scale—the tubipores, sertularia, cellularia, &c., exhibit something like a skeleton. They are contained within a strong case, from which they can extend themselves; whilst the corals and madrepores, on the other hand, have a central axis of hard material, the soft animal matter being, in a manner, seated upon it. But these substitutes for the skeleton are, like shell, foreign to the living animal; although in sustaining the softer substance and giving form, they may resemble bone.

The texture of a sponge, its form and elasticity, depends upon a membranous and horny substance, to which both silicious and calcareous spiculæ are added. Of shell, the hardening material is carbonate of lime, united to a membranous or cartilaginous animal matter. Paley describes the slime of a snail hardening into shell by the influence of the atmosphere: but that is a very imperfect, and indeed erroneous view. The shell of the oyster, and even the pearl, consists of concentric layers of membrane and carbonate of lime; and it is their laminated arrangement which causes the beautiful iridescence in the polished surface of those shells.* In the rough outer surface of an oyster shell, we shall see the marks of the successive layers: that which now forms the centre and utmost convexity of the shell was at an earlier age sufficient to cover the whole animal; but as the oyster grows, it throws out from its surface a new secretion, composed of animal matter and carbonate of lime,

* See the discoveries of Sir David Brewster on this subject: *Phil. Trans.* 1814, p. 397.

which is attached to the shell already formed, and projects farther at its edges. Thus the animal is not only protected by this covering, but as it increases in size, the shell is made thicker and stronger by successive layers.

The reader will not be unwilling that we should stop here to show that, rudely composed as this covering of the oyster seems to be, it not only answers the purpose of protecting the animal, but is shaped with as curious a destination to the vital functions of respiration and obtaining food, as anything we can survey in the higher animals. We cannot walk the streets without noticing that, in the fish-shops, the oysters are laid with their flat sides uppermost. They would die were it otherwise. The animal breathes and feeds by opening its shell, and thereby receiving a new portion of water into the concavity of its under shell; and if it did not thus open its lid, the water could neither be propelled through its branchiæ or respiratory apparatus, nor sifted for its food. It is in this manner that they lie in their native beds; were they on their flat surface, no food could be gathered, as it were, in their cup; and if exposed by the retreating tide, the opening of the shell would allow the water to escape, and leave them dry, thus depriving them of respiration as well as food.* We perceive, then, that the form of the oyster-shell, rude as it seems, is not a thing of chance. Since the shell is a cast of the body of the animal, the peculiar shape must have been given to the soft parts, in anticipation of that of the shell; an instance of prospective adaptation.

That the general conformation of the shell should have relation to what we may term its function, will be less surprising, when we find a minute mechanical intention in each layer of that shell. We should be inclined to say that the earthy matter of the shell crystallises, were it not that the striated or fibrous appearance differs in the direction of the fibres in each successive stratum—each layer having the striæ composing it parallel to one another, but directed obliquely to those of the layer previously formed, and the whole exhibiting a strong texture arranged upon well-known mechanical principles.

* In confirmation of these remarks, when the geologist sees the fossil shells in their strata, he can determine whether the oysters were overwhelmed in their native beds; or were rolled and scattered, as shells merely.

Shell is not alive, as true bone is. If the shell of any of the testacea be broken, the surface of the animal secretes a new shell: not, however, by the concretion of slime, but by the regular secretion of a substance combined of earthy and gelatinous matter.* Delicate experiments have been made by steeping shells in diluted nitric acid, by which it is shown that the carbonate of lime is the earthy material of shells; and that, when that earth is dissolved in the acid, a gelatinous substance of the form of the shell remains.

In crustaceous animals, such as the lobster and crab, the shell is formed of the same substances as the testacea, but with an addition of the phosphate to the carbonate of lime. A question arises, how these animals grow? It is found that they cast off their shells, and remain retired until a new and larger shell is secreted. Reaumur has given a very particular account of the process of separation, in the cray-fish.† In the shell of crustacea, we find an approximation to bone, inasmuch as it is articulated, and has certain processes directed inwards, to which the muscles are attached.

In the insect, the resisting material is deposited externally, and is converted to every purpose attained by means of an osseous system. Distinct members are formed, with the power of walking, leaping, flying, holding, spinning, and weaving. The hardened integuments, articulated and performing the office of bones, have like them spines and processes: with this difference, that their aspect is towards the centre, instead of projecting exteriorly. Were we to compare the system of resisting parts in man, and in the insect, we should be forced to acknowledge that the mechanical provisions in the lower animal are superior! The first advantage of the skeleton in the insect‡ being external, and removed from the influence of the circulation, is, that it is capable of having greater hardness and strength imparted to it, according to the necessities of the animal, than can be bestowed upon bone. True bone, being internal, and depend-

* We owe our knowledge of the formation of shell to the great French naturalist Reaumur; who, by ingenious experiments, showed the distinction between shell and bone, and that the former was secreted from the surface of the animal.

† See a paper by Sir John Dalzell, on the Exuviation of the Crustacea: *Transactions of British Association*, 1851, p. 120.

‡ It is termed "exoskeleton," as contrasted with the "endoskeleton," or internal skeleton.

ing for its growth and vitality on the blood-vessels which penetrate it, must be porous and soft. The next advantage in the exterior crust or skeleton, is mechanical; the hard material is proportionately stronger, to resist fracture, and bear the action of muscles, according as it is removed to a distance from the centre: now the muscles in the insect, instead of surrounding the bones, as in the higher animals, are contained within the shell; consequently the shell is so much the further thrown off from the axis of the limb; and increased strength is thus obtained.

When considering the larger vertebral animals, we had reason to say that a correspondence is preserved between the resistance of the bones, and the power of the muscles; and we may indulge the same reflection here. As the integument covering the insect is much harder than bone, so are the muscles stronger, compared with those of the vertebrata. From the time of Socrates, have comparisons been made between the strength of the horse and that of the insect; to the undoubted superiority of the insect.

As goodly a volume has been written on the muscles of a caterpillar, as has ever been dedicated to human myology; the most minute anatomical description has been given of the caterpillar which feeds upon the willow.* And here we learn that the annular construction of the hard integument determines the plan of the whole anatomy—the arrangement of the muscles, even the distribution of the nerves. Each ring has its three sets of muscles; direct and oblique; traversing and interweaving, but yet distinct and symmetrical; and all as capable of being minutely defined, as have been those of the human body by Albinus. Corresponding to these muscles, the system of nerves is delicately laid down. In short, we allow ourselves to be misled in supposing that animals, either of minute size, or low in the scale of arrangement, exhibit any neglect or imperfection. Even if they were more simple in structure, the admiration should be the greater: since all have the functions necessary to life in full operation.

We may perceive that a certain firm substance, calculated to sustain the more strictly living part, and to give strength, is

* The work referred to is by Lyonnet, who reckons four thousand and sixty-one muscles in this caterpillar.

traceable through all living bodies. In the vegetable, it is the woody fibre; and there sometimes, as if to mark the analogy, we have silicious earth deposited, instead of the phosphate and carbonate of lime of the animal structure. In the lower animals, we find membranes capable of secreting a solid material; and although, in some instances, that substance resembles leather or cartilage, it is, in general, earthy, and, for the most part, consists of carbonate of lime. But when elasticity, as well as general resistance, is necessary, cartilage is employed; a highly compressible and elastic substance. Thus, fishes have a large proportion of cartilage in their bones; and some, from having it in greater quantity, are called cartilaginous, in distinction to the osseous or true fishes. The cartilaginous and elastic structure comes into use in an unexpected manner in the fish; when the salmon or trout leaps from the water, the muscles of one side first bend the spine; as they relax, the spine recoils: hence its elasticity assists the action of the muscles of the opposite side: and thus these two forces combine to give a powerful stroke on the water with the tail, and the fish makes its bound.

MECHANICAL PROPERTIES OF BONE, OR OF THE TRUE SKELETON.

Those considerations lead us to understand more readily the composition of bone. It consists of three parts, having different properties—membrane, cartilage, and phosphate of lime. By these various substances being united in its texture, bone is enabled to resist stretching, torsion, and compression. If there had been a superabundance of the earthy parts, it would have broken like a piece of porcelain; and if it had not possessed toughness and some degree of elasticity, it would not have enabled a man to pull, and push, and twist. [The earthy substance is not merely united with the cartilage or gelatinous matter; but membranes and vessels enter into the composition of bone. Bone is not excreted, or foreign to the system of the animal body; on the contrary, it participates in those laws that govern living matter. It is continually undergoing changes of deposition and absorption, through the influence of blood-vessels and absorbing vessels; by which means it grows with the growth of the soft parts.

In fishes, which live in an element that supports the weight, the bones have a very large proportion of elastic cartilage in

their composition; and some, as we have already remarked, possess so little phosphate of lime, as to be denominated cartilaginous fishes. Indeed, in the higher classes of animals which live upon land, there is, in the different bones, a finely appropriated union of earth, cartilage, and fibre; so as to give to each respectively the due proportion of resistance, elasticity, and toughness. Not only is the bone of each class of animal peculiar in the proportion of its ingredients; but each bone of the skeleton, as of man, has a due proportion of earth, cartilage, and fibre, to suit its office. The temporal bone, in which the ear is situated, is as dense as marble (it is called *os petrosum*), and of course is suited to propagate the vibration of sound; the heel-bone, or projection of the elbow, on which the powerful muscles pull, is, on the other hand, fibrous, as if partaking of the nature of a tendon or rope; whilst the columnar bones, which support the weight, have an intermediate degree of density, and an admirable form, as we shall see presently.

Looking to the hard texture of bone, we should scarcely suppose that it was elastic. But if ivory possess elasticity, this property cannot be denied to bone. A billiard ball being put upon a marble slab, recently painted, a very small spot will mark the point of contact; but if we let the ball drop upon the marble from a height, we shall find the spot much larger; because the elasticity of the ivory has permitted the ball to yield, and to assume momentarily an oblate spheroidal form.

When a new principle is admitted into a complex fabric, the utmost ingenuity can hardly anticipate all the results. Elasticity is extensively employed in the machinery of the animal body. Now, to show how finely it must be apportioned, we may take the illustration of a bridge, built of iron, instead of stone, and having a certain swing and elasticity. It lately happened that a bridge of that construction fell; and it was under very curious circumstances—by the marching of a body of soldiers over it. The bridge was calculated to sustain a greater weight than that of the body of men; and had they walked tumultuously over it, it would have withstood the pressure. But the soldiers marched to time across it: accordingly, they accumulated a motion in the bridge, consequent on the elasticity of the material; which swinging motion, added to their weight, broke it down. This may give us some idea how finely adjusted the

different qualities in the solid material of the animal fabric must be; not merely to enable it to sustain the incumbent weight, or to resist transverse or oblique impulses, but to withstand the frequent and regularly-repeated forces to which it may be subject in the various actions of the body. It gives interest to this fact, that hardly is there a bone which has not a constitution of its own, or a disposition of its material adjusted to its place and use: the heel-bone, the shin-bone, the vertebræ, and the bones of the head, all differ in their mechanical construction.

This explanation of the use of the prominent ridges of a bone, imparts a new interest to osteology. The anatomist ought, from the form of the ridges, to deduce the motions of the limb, the forces bearing upon the bone, and the nature and common place of fracture; while, to the general inquirer, an agreeable course of reasoning is introduced into a department, which, when the "*irregularities*" of the bone are spoken of as if they were the accidental consequences of the pressure of the flesh upon it, is altogether barren of interest. It is perhaps not far removed from our proper object to remark, that a person of feeble texture and indolent habits, has the bone smooth, thin, and light; but that nature, solicitous for our safety in a manner which we could not anticipate, combines with the powerful muscular frame, a dense and perfect texture of bone, where every spine and tubercle is completely developed. And thus the inert and mechanical provisions of the bone always bear relation to the living muscular power of the limb; and exercise is as necessary to the perfect constitution and form of a bone, as it is to the increase of the muscular power.

Jockeys speak correctly enough when they use the term "*blood and bone*," as distinguishing the breed or genealogy of horses; for blood is an allowable term for the race, and bone is so far significant, that the bone of a running horse is remarkably compact, compared with the bone of a draught horse. The reader can easily understand, that in the gallop, the horse must come on his fore-legs with a shock proportioned to the span; and that, as in man, the greater his muscular power, the denser and stronger must be the bone.

As the bones are not mere pillars, intended to bear a perpendicular weight, we ought not to expect uniformity in their

shape. According to its place, each bone bears up against the varying forces applied to it. Consider two men wrestling together, and then think how various must be the direction of the resistances: now they are pulling, and the bones are like ropes; or again they are writhing and twisting, and the bones bear a force like the axle-tree between two wheels; or the bones are like pillars, under a great weight; or they are acting as levers. We see, therefore, why a bone, to withstand these different shocks, should consist, as we have stated, of three parts: the *earth* of bone (phosphate of lime) to give it firmness; *fibres* to give it toughness; and *cartilage* to give it elasticity.]

Let us compare the machinery of some complicated engine with the mechanical properties in an animal body, that we may comprehend what is most truly admirable in the latter. Suppose the engineer has contrived a steam carriage; that with the utmost possible precision he has calculated the power of the steam, the pressure of the atmosphere, the strength of the tubes and cylinder, the weight to be moved, and the friction of the whole machinery. At length, the engine is constructed. But, on trial, it remains immoveable. After much thought, the cause of the impediment is discovered, the pressure is eased, or the friction diminished; and, to the admiration of the beholders, the carriage actually moves—till, in course of time, a pipe bursts. This, however is mended; the whole is improved, and a day is appointed for a great trial. The engine now runs for half a mile, and first a bolt is shaken loose, then a spring snaps; but, at length, with renewed ingenuity and labour, and much correction, after a few months, the carriage actually runs a stage. By this comparison we are taught how much, even in the mere machinery of the animal frame, before the powers of life are measured out to it, is to be admired. Such, for example, as the force of the heart to propel the blood; the resistance of the tubes to the circulating fluids; the proportioning of the strength of the limbs to the weight of the body; the adjustment of the power of the muscles to the length of the bones, as levers; the flexibility of the joints; the density of the bones to resist pressure or weight; their elasticity to prevent concussion and fracture. In the animal body, so finely are the active and resisting powers balanced, that no accident occurs from disproportioned forces; no second trial is wanted, to increase the

power, or strengthen the levers, or add to the elasticity of the springs. It is at once perfect; perfect to its end. But to understand that fully, and the adaptations in the constitution of the bones, we must proceed a little deeper in our investigation.

It has been already said, that perfect security against accidents, in the animal body, and in man especially, is not consistent with the scheme of nature. Without the precautions, and the continued calls to exertion, which danger and the uncertainty of life produce, many of the faculties of the mind would remain unexercised. Whence, else, would come courage, resolution, and all the manly virtues? Take away the influence of the uncertain duration of life, and we must suppose also a change in the whole moral constitution of man. Whether we consider the bones as formed to protect important organs, as in the skull; or levers for the attachment of the muscles, as in the limbs; or in both capacities, as in the texture of the chest—while they are perfectly adapted to their function, they are yet subject to derangements from accident. The mechanical adaptations are sufficient to their ends, and afford safety, in the natural exercises of the body. To these exercises there is an intuitive impulse, ordered with a relation to the strength of the frame of the body; for by the admonitions of pain we are deterred from the excessive or dangerous use of the limbs.

The bones of the extremities are termed hollow cylinders. Now, after having convinced ourselves of the necessity of the cylindrical form for the bones of the limbs, as it is that which combines strength with lightness, we may find, upon a more particular examination, that they vary in their shape, in many instances: and we may even, at last, be prone to believe that there is much chance or irregularity in their forms. But such a conception is quite inconsistent with a correct knowledge of the skeleton; and as it leads to further mistakes, we shall take pains to show,—first, why the bones are hollow cylinders; and secondly, why they vary in shape, so as to appear to the superficial observer irregular.

The reasoning that serves to explain the admirable structure of the hollow cylindrical bone, applies equally to many other natural forms; as that of a quill, a reed, or a straw. And this last example may remind us of the saying of that unfortunate

man, who being drawn from his cell, before the Inquisition, was accused of denying that there is a God; picking up a straw which had stuck to his garments, he said, "If there were nothing else in nature to teach me the existence of a Deity, this straw would be sufficient."

It hardly requires demonstration that, having a given mass of material with which to construct a pillar or column, the hollow cylinder will be the form of greatest strength. The experiments of Du Hamel on the strength of beams, afford us the best illustrations as to how the material should be arranged to resist transverse fracture. When a beam, resting on its extremities, sustains a weight upon its centre, it admits of being divided into three portions, each being in a different condition with regard to the weight: the lower part resists fracture by its toughness; the upper part, by its density and resistance to compression; and the portion between these is not acted upon at all. This middle part might, therefore, be taken away, without any considerable weakening of the beam: or it might be added to the upper or the lower part, with great advantage. In illustration of this; when a tree is blown down, and broken at its trunk, the fractured part gapes to the windward—where the wood has been torn asunder like the snapping of a rope: to the leeward, the woody fibres are crushed into one another and splintered—having given way to the compression; while the central part is merely bent, not wholly fractured.

It can be readily understood how a tougher substance added to the lower part, would strengthen the beam: we see it in the skin laid along the back part of the Indian's bow; or in the leather of a carriage spring. Again, the following is a beautiful experiment to demonstrate the quality in the upper portion of the timber by which the weight is resisted: if a part, amounting to nearly a third of the beam, be cut away, and a denser piece of wood be nicely let into the space, the strength will be increased; because the hardness of the new piece of wood is calculated to withstand compression. This experiment I like the better because it explains an interesting peculiarity in the construction of the cylindrical bones; namely, a difference in the density of the several parts or sides of the bones. In reading anatomical books, we are led to suppose that the pressure of the muscles which surround the bones, has the effect of moulding

them into their particular forms. This is a mistake. Were we to admit the truth of such an explanation, it would be the same as admitting an imperfection in the design : and we should expect to find, that if the bones yielded at all to the force of the muscles, they would give way more and more, according as the power of the muscles increased, until they were ultimately destroyed. Nothing, however, in the living frame is more admirable than the relation established between the muscular power and the strength, or capacity of passive resistance, in the bones. The deviations from the cylindrical form are not irregularities. If we take for our example the chief bone of the leg, the tibia, or shin-bone, which, of all others, varies the most from the cylindrical shape, we shall have the best demonstration of the correspondence between the form of the bone and the force which it has to sustain. When we consider the direction in which the force falls upon the tibia, as we put the foot to the ground, in walking, running, leaping, or in any of the powerful exertions where the weight of the body is thrown forwards on the ball of the great toe, it must appear that the pressure comes chiefly on the anterior part. Accordingly, if the tibia were a perfect cylinder, it would be subject to fracture, even from the mere force of the body, when thrown upon it. But if a column be rendered stronger, by the material being accumulated to a distance from the centre, we readily perceive the advantage gained by a spine or ridge being formed upon the front of the tibia. Again, if we examine the internal structure of that spine, we shall find that it is much denser and stronger than the rest of the bone. No one, therefore, can deem the deviation from the regular cylindrical form, or the density of this ridge, a thing of accident; it corresponds so perfectly with the experiment of Du Hamel, where a dense piece of wood being let into the beam of timber, had the effect of increasing its power of resisting transverse fracture. With the knowledge of these facts, were we to proceed to examine all the different bones of the skeleton, we should find, everywhere, that the form was in strict relation either to the motion to be performed, or the strain to which the bone was most exposed.

In comparing the true bones of the higher animals with the coverings of insects, we observed the necessity for the former being of a porous structure; and how inferior they were in

strength from that cause. If the texture of a bone be very dense, it will not re-unite, upon being fractured; and, if exposed, it will die. Here, then, is an obvious defect: the bones of animals cannot be made capable of sustaining great weight, without losing a property necessary to their existence—that of restoration on being injured. And even were the material very much condensed, it does not appear that the phosphate of lime, united as it is with the animal matter, would be capable of withstanding great compression. Accordingly, a limit is put to the size of animals. This may, perhaps, countenance the belief that, in size and duration of life, animals bear a relation to the powers and life of man—that it was only in a former condition of the world, that creatures of the greatest dimensions could exist. Our allusion here is to such animals only as have their huge bulk resting on extremities; for, with respect to the whale, it lies out buoyed and supported in the water. Some of those great fossil animals, the remains of which are found in the secondary strata, are estimated to have been seventy feet in length; and they had extremities; but the thigh and leg did not exceed eight feet in length, while the foot extended to six feet; a proportion which implies that the extremities assisted the animal to crawl, rather than to bear its weight, like the extremities of the mammalia. However, in the larger terrestrial animals, the material of the bones is found to be dense, and their cavities filled up; the diameters of those of the extremities, together with their spines and processes, being remarkably increased. Nothing can be conceived more clumsy than the bones of the megatherium. Hence it really appears as if nature had exhausted her resources, with respect to this material: that living and vascular bone could not be moulded into a form capable of sustaining the bulk and weight of an animal much superior in size to the elephant, mastodon, or megatherium.

[The subject may be illustrated in this manner:—A soft stone projecting from a wall, may make a stile strong enough to bear a person's weight; but if it be necessary to double the length of the stile, the thickness must be more than doubled, or a freestone substituted: and were it necessary to make this freestone project twice as far from the wall, it would not be strong enough to bear a proportioned increase of weight, even if doubled in thickness; granite must be placed in its stead;

and even granite would not be capable of sustaining four times the weight which the soft stone bore in the first instance. In the same way, the stones which form an arch, of a large span, must be of the hardest granite, or their own weight will crush them. The same principle is applicable to the bones of animals: the material of bone is too soft to admit of an indefinite increase of weight. It is another illustration of what was before stated, that a relation is established through all nature; that the structure of the very animals which move upon the surface of the earth is proportioned to its magnitude, and the gravitation to its centre.]

OF THE JOINTS.

With regard to the articulation of the bones at the joints, we cannot mistake the reason why the surfaces of contact should be enlarged; the expansion of the ends of the bones makes them sit more securely upon each other, thereby diminishing the danger of dislocation. And this advantage is gained without detriment to the motion of the joint. In machinery, when the weight or pressure are the same, an increase in the extent of the surfaces in contact does not add to the friction. For example, if a stone, or piece of timber, of the shape of a book or a brick, be laid upon a flat surface, and drawn across it, it will be moved with equal facility whether it rest upon its edge, or upon its side. In the same manner, the friction between the articular surfaces of the bones of the knee-joint, is not increased by their greater diameter; while obvious advantages result from their additional breadth: the ligaments knit the bones more strongly; and the tendons being removed to a distance from the centre of motion, more power is given to the action of the muscles.

[In comparing the skeleton with carpentry, or with anything artificial that may admit of comparison with it, we remark an absence of straight lines or regular forms in the various bones, whether they serve the purposes of shafts, axles, or levers; while, in the mechanism made by man, every part is levelled and squared, or formed according to some geometrical line or curve. This, as we have said, leads the superficial thinker to conclude, that the bones are formed irregularly, or without reference to principle. But the consideration of by Whom

formed, leads to a review; and a deeper examination brings with it the conviction that the curves, spines, and protuberances of the bones, where they enter into the joints, are formed with a relation to the weight which they bear, and the thrusts and twists to which they are subjected, in the different motions of the body. If we observe the various postures of a man at any manual labour, or under a weight, or running, or leaping, or wrestling, we shall be convinced that no carpentry of the bones, formed according to geometrical lines or curves, could suit all this variety of motion. No splicing, dove-tailing, cogging, or any of all the various shapes into which the carpenter or joiner cuts his material, could enable them to withstand the motions of the body, where it is so utterly impossible to estimate the forces, or to calculate upon the variety in their direction.

That the varieties in the forms of the joints are not irregular or accidental, but are related to the motions to be performed, is apparent in the close examination of the human skeleton; and it is still more clearly evinced by comparative anatomy. To comprehend the fine adjustment of each bone in its articulation, we should require to go more minutely into the anatomy than is suitable to this work. Then we should find with what curious mechanical adaptation the motions are permitted in the prescribed direction, and checked in every other. We should observe how the motions of one joint are related to those of another; and how, by the combination of joints, each of which is securely checked and strengthened, facility and extent of motion are produced in the whole: for example, in the arm and hand, where the motions are free, and varied in every possible direction.

It is interesting to see how the joints of the lower extremities in man are modified, in comparison with those of the upper. We have elsewhere remarked that the bones of the human pelvis, thigh, and leg exceed those of all other animals in relative size; which is a provision for the erect position of man. The same design is evinced in the form of the ankle, knee, and hip-joints. Whilst in their combination they give every necessary degree of motion consistent with security, there is a happy adaptation of each to produce at once firmness and mobility. That is to say, when the limb is thrown forward in walking or

running, the whole member is loose, and capable of being freely directed; so that we plant it with every convenience to the irregularity of the ground; but when the body is carried forward, and the weight comes to be perpendicular over the limb, it acquires, by the curious adjustment of the bones, a firmness equal to that of a post. Again, when the body is still further thrown forward, and the limb is disencumbered of the weight of the body, the joints are let loose, so as to be bent easily, and to obey the action of the muscles.]

OF THE MUSCULAR AND ELASTIC FORCES.

Elastic ligaments are liberally supplied in the human spine: a range of peculiar ligaments run along the course of the column, and are highly elastic. The *ligamentum nuchæ* is that ligament which extends from the prominence of the spine between the shoulders, to the back of the head; and the student who hangs his head over his book, enjoys the advantage of this elastic support. We may trace the same ligament, with increasing strength, from that which sustains a man's head, to the powerful elastic structure in the neck of the elephant, which, like the spring of a steel-yard, weighs against its immense head and tusks.

These elastic ligaments vary with the length and motion of the neck. It would be tedious to describe their varieties in the camel, camelopard, ostrich, &c. We may be satisfied with the fact, that the elastic ligament is a structure extensively used in the animal textures; generally coming in aid of the muscles, or as a substitute for them.

The muscular power is contrasted with the elastic, as being a property of motion possessed exclusively by a living part, the muscular fibre. We acquiesce in the distinction, since the fibre ceases to have irritability or power after death; while the elastic structures retain their peculiar quality. But yet there is a property in the elasticity of the living body, which cannot be preserved after death. To illustrate this, let us take the instance of the catgut string of a harp, and suppose that it is screwed tightly, so as to vibrate in a given time, and sound the note correctly; if it be struck rudely, it will be put out of tune; that is, it will be stretched and somewhat relaxed, and no longer vibrate in time. But this will not take place in the living elastic

fibre; in it there is a power of restoring the property. If we see the tuner screwing up the harp-string, and with difficulty, and after repeated trials, with the tuning-fork, and with his utmost acquired skill, bringing it to its due tension, and restoring it to its former elasticity, we have a demonstration of how much Life is performing, after every act of over-exertion, in repairing the fibres of the animal frame. The more powerful the active forces of the body are, the more carefully is the proper tension of the tendons, ligaments, and heart-cords preserved.

Or we may take the example of a steel spring. A piece of steel, heated to a white heat, and plunged into cold water, acquires certain properties; and if heated again to 500° of Fahrenheit, it becomes elastic; possessing what is called a "spring temper," so that it will recoil and vibrate. But if this spring be bent in a degree too much, it will be deprived of part of its elasticity. In the living body, should a similar thing happen to one of the elastic structures, it has a power of restoration, which the steel has not.

[The safeguard against the excess of muscular power is in the elasticity of the parts. This is obvious in the limbs and general texture of the frame; but it is most perfectly exhibited in the organs of circulation. If the action of the Heart impelled the blood against parts of solid structure, they would quickly yield. When, by accident, this does take place, even the dense bone is very soon destroyed. But the coats of the artery which receive the rush of blood from the heart, although thin, are limber and elastic; and by this elasticity or yielding, they take off or subdue the shock of the heart's action, while no force is lost; for as the elastic artery has yielded to the sudden impulse of the heart, it contracts by elasticity in the interval of the heart's pulsation; and the blood continues to be propelled onward in the course of the circulation, without interruption, though regularly accelerated by the pulse of the heart.

If a steam-engine were used to force water along pipes, without the intervention of some elastic body, the water would not flow continuously, but in jerks; therefore, a reservoir is constructed, containing air, into which the water is forced, against the elasticity of the air. Thus, each stroke of the piston is not perceptibly communicated to the conduit-pipe, because the intervals are supplied by the resilience of the compressed air. The

office of the reservoir containing air, is performed in the animal body by the elasticity of the coats of the arteries; by which means the blood flows uninterruptedly into the arteries, and has a continuous flow in the veins beyond them.

But as life advances, the arterial system loses much of its elasticity, and becomes rigid. This is so common an occurrence that we can no more call it a disease than the stiffened joints of an old man; it is the forerunner or the accompaniment of the decline of life. Sometimes this change takes place too early in life, and to an extreme degree; and from its effects we must call it morbid; for it not unfrequently happens that the muscular power of the heart being still entire and vigorous, the arteries can no longer withstand it. They have lost that power which, yielding to the heart's action, resists, recoils, and the more it gives way, the more it takes off the suddenness of the shock; which, in yielding, wastes no power, since the recoil gives as much force to the acceleration of the blood, as was lost of the heart's action. The artery, then, being rigid, yields indeed to the heart's impulse, but has no rebound. It becomes permanently dilated or enlarged; and is called aneurismal. A stronger beat of the heart, excited by inordinate action or passion, chips and bursts the now rigid coats of the artery. If the breach be gradual, a pouch forms—a true aneurism. And here is the proof we require; for this bag coming to pulsate upon the solid bones, they are absorbed. That action of the heart, which was so lightly and so easily borne whilst the vessels were elastic, now beating upon a solid structure, in a short time destroys it. Thus, from what takes place on a very slight derangement of the properties of the parts, we are led to a more accurate knowledge of the fine adjustment of the active and resisting properties in the circulating vessels, during youth and health.

A piece of rope, of a new patent, has been shown to us, which is said to be many times stronger than any other rope of a like diameter. It is so far formed upon the same principle as the tendon of a muscle, that the strands are plaited, instead of being twisted: but the tendon has still a superiority; for the lesser yarns of each strand in it, are interwoven with those of other strands. It may be asked, however, do not the tendons of the human body sometimes break? They do; and in circumstances which only add to the interest of the subject. By the

exercise of the tendons, (and their exercise is the act of being pulled upon by the muscles, or having a strain on them,) they get firmer and stronger; but in the failure of muscular activity, they become less capable of resisting the tug made upon them; and if, after a long confinement, a man has some powerful excitement to muscular exertion, then the tendon breaks. An old gentleman, whose habits have been staid and sedentary, and who is very guarded in his walk, is upon an annual festival tempted to join the young people in a dance; then he breaks his *tendo Achillis.* This reminds us that we are speaking of a living body; and that, in estimating the mechanical properties, we ought not to forget the influence of Life, and the law that the natural exercise of the parts, whether they be active or passive, is the stimulus to the circulation through them, and to their growth and perfection.]

ON THE POSITION OF THE HEAD OF ANIMALS, AND ITS RELATION TO THE SPINE.

To illustrate the proposition, that "all parts of the skeleton are correlated; and that the variations in their form depend on the functions."

It has been shown in the text, when treating of the upper or anterior extremity, that the changes of form exhibited in different animals, may be referred to one principle—the adaptation of the parts to their proper uses. The head, in certain animals, may be considered as performing in some measure the office of hands. Now, if we adopt this view, we shall be able to judge more correctly how far it holds true that the centre of the skeleton, to which the head belongs, remains permanent in its form, compared with the extreme parts.

We have seen that it is the opinion of some naturalists, that all the varieties in the conformation of the skeleton admit of being explained according to a law, by which the central parts preserve an uniform shape, whilst the extremities are incident to change. That opinion I shall controvert, and show that although the spine and head, in retaining their office, common to all vertebrated animals, of protecting the brain and spinal marrow, are permanent in regard to them, yet they vary in the shapes of their processes, and in their relations to the adjacent parts. Pursuing that idea, we shall be able to account for the characteristic forms of animals.

The principle, then, which will guide us, both here and in a more universal survey of animal nature, is, that the organisation varies in correspondence with the condition in which the animal is placed, in reference to procuring food, and multiplying its species. If we consider any of the great functions on which life depends, we shall perceive that the apparatus is altered and adapted to every changing circumstance. Digestion, for example, is the same in all animals; but the organisation presents numerous interesting varieties. Whether it be in the quadruped, the bird, the fish, or the insect, the stomach

varies both in its form and the number of its cavities, in accordance with the nature of the food which it receives. And the variation does not depend upon the size or form of the animal: it is adapted purely to the conversion of its particular food into nourishment: the gizzard of the fish, or of the insect, is as perfect as that of the fowl. So with the decarbonisation of the blood in breathing: the process of throwing off the carbon is the same in all living animals; but the mode in which respiration is performed varies according to circumstances; the apparatus is especially modified and adjusted, according as it is carried on in the atmosphere or the water.

But although the organs subservient to the grand functions,—the heart and blood-vessels, the lungs, the stomach,—be variously adapted to the different classes of animals, they change much less than the parts by which animals are enabled to pursue their prey or obtain their food. Their extremities, by which they walk, or run, or creep, or cling, must vary infinitely. And so their teeth and horns, and the position of their head, and the strength of their neck, exhibit nearly as much variety as their proper extremities; because these parts likewise must be adapted to their different modes of obtaining food, or of combating their enemies.

Following this principle, therefore, let us observe the forms of some of the more remarkably-shaped animals, and endeavour to explain their meaning. When we look upon the boar's head, its form alone enables us to comprehend something of the habits of the animal; we see the direction in which he will employ his strength. He lives by digging up roots; and the instruments by which he feeds are also those by which he defends himself—the position of his tusks protects his eyes in rushing through the underwood; but the formation of the skull, and of the spine, and the mass of muscle in the neck, all show the intention of his configuration to be, that he may drive onward with his whole weight and strength, and rend with his tusks. Accordingly, the back part of the skull rises in remarkable spines or ridges for the attachment of muscles; and corresponding with them, the spinous processes of the vertebræ of the neck and back are of extraordinary length and strength. Processes of such dimensions as these distinctly indicate the immense power of the muscles which pass from the neck to the head. We now

understand the reason of the shortness and inflexibility of the neck of the boar; it is so formed because the strength of the shoulders is directed to the head, or, we may say, to the large tusks. An elongated and flexible neck would have rendered these implements useless. The characteristic form of the wild boar, then, consists in the height of the back, the shortness and thickness of the neck, the wedge shape of the head, the projection of the tusks, and the shortness of the fore-legs, which must always be in proportion to the neck.

Thus we perceive that the skull, unaffected in its office of containing and protecting the brain, is yet subject to variations in its form and place, according to its other functions;—that it is adapted, just as the extremities are, to the animal's mode of life. In the same manner, we see the spine permanent in its office as a tube to protect the spinal marrow, but yet varying in its processes and articulations, as they bear a reference to the skull. In short, although these be the very central parts of all, they undergo changes of form in due accommodation to the whole skeleton.

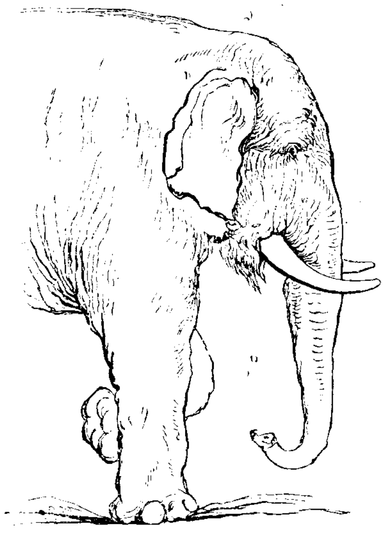
What a complete contrast there is between the wild boar and any of the feline tribe! But it is a contrast of form and motion, at once referable to their spine. In the tiger or leopard, the perfect flexibility of the body, and the almost vermicular motion of the spine, correspond to the teeth and jaws, and the free use of the paws.

The peculiarity of the elephant's configuration has been happily illustrated by Cuvier: and the principle may be pursued in a manner interesting both to the naturalist and geologist.

In ourselves, we may feel between the shoulders a certain projection of the spine, which is called the *vertebra prominens;* and if we stoop forward, as in reading a book which lies upon the table, a ligament will be felt extending from that process to the back of the head. This ligament suspends the head, and relieves the muscles. But as man for the most part carries his head balanced on the extremity of the spine, or can vary its relation under fatigue, the strength of that suspensory ligament is not to be compared with the corresponding part in quadrupeds; where, from the horizontal position of the spine, the head always hangs: and where there would be a great waste of muscular exertion, but for the interposition of this elastic liga-

ment. In the horse it is long and strong; and the admirable thing is, the accurate adjustment of the elasticity of this ligament to the weight and position of the head: the head is nicely balanced by it, as on a steelyard. With this circumstance in our mind, let us observe the peculiar form of the elephant.

1. As in treating of the boar, we begin again by observing the teeth. Now, one grinder tooth of the elephant weighs seventeen pounds;* and of these there are four in the skull, besides the rudiments of others. 2. We next observe how admirably these teeth are suited to sustain great pressure and attrition. 3. The jaws must be constructed of a sufficient size, not only to afford a deep socketing to the teeth, but to give lodgment to muscles strong enough to move this large grinding machine. 4. The animal must be provided for its defence too. Now each of the tusks sometimes weighs as much as one hundred and thirteen pounds: and projecting as they do, they may be considered as placed at the extremity of a long lever. 5. If



this enormous and heavy head had hung on the end of a neck of anything like the proportions in the horse, the pressure on the anterior extremities would have been inordinate; and more than four times the expenditure of muscular power would have been necessary to the motion of the head. 6. What has been the resource of nature? There are seven vertebræ of the neck in this animal (the same number that we count in the

* The natural tooth weighed seventeen pounds, the fossil tooth sixteen-and-a-half pounds.

giraffe); but these bones are compressed into a small space in a very remarkable manner; and thus the head is brought close upon the body, so as to appear a part of the body, without the interposition of any neck. 7. But the animal must feed: and since its head, owing to the short neck, cannot reach the ground, it must possess an instrument, like a hand, in the proboscis—to minister to the mouth, to grasp the herbage, and lift it to its lips.* Thus we perceive that the conformation of the elephant, as regards the peculiar character of his figure, in the shoulders and head, in the closeness of the head to the body, in the possession of the proboscis, and the defence of that proboscis by the projecting tusks,—is a necessary adaptation to the great weight of the head, and, indeed, of the general large size of the animal.

We may carry the inquiry a little further, to the effect of elucidating a very curious part of natural history. The Mastodon is the name of an extinct animal, which must have been nearly of the same size as the elephant. It has received that name from the early familiarity of naturalists with the teeth; which have upon their surfaces of contact mamillary-shaped projections. It was supposed, at one time, that these teeth belonged to a carnivorous animal. But a portion of the upper jaw, with the teeth preserved in it, being found, it admitted of this course of reasoning:—In the superior maxillary bone of all vertebrated animals, there is a hole for transmitting a branch of the fifth nerve which goes to the upper lip;† when, however, as in the elephant, a great proboscis is added to the lip, it follows that, as that organ possesses its sensibility through the same branch of the fifth, not only will the nerve itself be proportionably large, but the hole through which it is transmitted, will be increased in diameter. Accordingly, when a fragment of the upper jaw-bone in which that hole is preserved is found, we can infer from the greater size of the orifice, that the nerve supplied more than a mere upper lip—that, as in the case of the mastodon, the animal had a proboscis, and was a species of elephant.

Let us consider the principle in another light. How are the

* Anguimanus, was a name given to the elephant by Lucretius:—

"The beast who hath between his eyes
The serpent for a hand."

† See page 103.

neck and head of an animal accommodated to feeding, when the neck is short, and there is no proboscis? The *elk* is a strange, uncouth animal—principally from the setting on of its head. The weight of the horns is enormous: and if the head and horns were placed at the extremity of an elongated neck, it *would* be preposterous; they would, in fact, overbalance the body. It is for that reason, we presume, that the head is so curiously approximated to the trunk. We observe, in the next place, a want of relation between the fore-legs and the neck—*that the legs are of great length, while the neck is extremely* short. Now it is interesting to find that the animal does not browse upon the herbage at its feet; it feeds off the sides of the

rocks! A very remarkable proof of the incapacity of this animal to feed in the common way, was afforded by an accident which befell a fine male specimen confined in the Zoological Gardens. To reach the ground, on which his food was unintentionally scattered, he had to extend out his fore-legs laterally;

in this position his foot slipped, he dislocated his shoulder, and *died of the accident.*

Contrasted in a most remarkable manner with the elk, we have the giraffe. The giraffe feeds upon the branches of lofty trees; and the whole constitution and form of the animal are provided to enable it to reach high—the fore-legs are long, the neck still longer, the head is remarkably small and light, and the tongue has a power of elongation which no other quadruped possesses. The tongue, indeed, is not inaptly compared with the trunk of the elephant; it can be extended seventeen inches; it can be twisted about so as to resemble a long black worm; and it is used with extraordinary dexterity, in picking up a straw, as well as pulling down a branch. The relative proportions of the skeleton of the giraffe are full of interest, as showing the accommodation in the structure to the necessities of the animal.

And, first, of the head: if we have the skull of the giraffe before us, and compare it with that of the camel or horse, we shall be struck with the delicacy of the bony textures of the former, with its being cellular, thin, and light as a paper case. Now, can there be anything more obvious than that this lightness of texture is provided in consequence of the extraordinary length of the neck? Had the skull of the giraffe been as strong and heavy as that of the horse or camel, it would have preponderated too much at the extremity of such a neck.

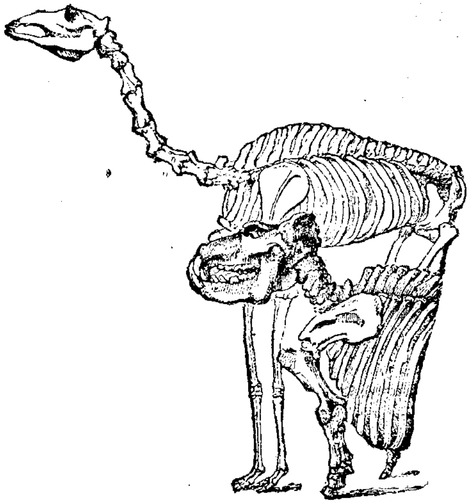
Secondly, as to the spine: there is an accommodation in the form and position of this part also. In most quadrupeds, the spine lies horizontally: but if the bones had been so placed in the giraffe, the whole weight of the shoulders, neck, and head would have been thrown on the anterior extremities. This, however, is prevented by the anterior extremities being much longer than the posterior: whence it results that the trunk is placed in an oblique, or semi-erect position; and, accordingly, a portion of the weight of the neck and head, parts which in other creatures are sustained altogether by the fore-legs, falls upon the hind-legs.*

Thirdly, on looking to the ribs, we observe another peculiarity of form; which may be accounted for on the same consideration of the length, and consequent weight, of the neck and head. The chest is supported, of course, upon the anterior extremities:

* The ligamentum nuchæ in this animal extends the whole length of the spine, from the os sacrum to the skull.

but the ribs in front, which rest upon the legs and bear the principal pressure, are of great comparative strength; while the posterior ones, by their delicacy, weakness, and mobility in breathing, present a singular contrast to them. In short, the fore part of the chest, which in a manner intervenes between the neck and anterior extremities, requires its compages to be particularly firm and strong, for supporting the superincumbent weight: while the motions of respiration are performed chiefly by the posterior ribs.

Although the proportions between the neck and the legs, in this creature, may seem to be duly preserved, yet he is not suited to browse the grass: his proper food is the leaves on the high branches of trees. In attempting to reach the ground with his mouth, his limbs appear to be in danger of suffering dislocation; he extends his feet laterally, elevates the scapulæ, draws in the crupper, and stretches the neck, so as to present a very ludicrous figure.



Camel and Hippopotamus.

We have here a sketch of the skeletons of the hippopotamus and of the camel, as they stood accidentally contrasted in the

Museum. The head of the hippopotamus is of great strength and weight, and it is appended to a short neck; in the shortness of its legs also, we see the correspondence which we have had occasion to remark between the position of the head, and the height of the trunk from the ground. The form of the camel is, in every respect, different. This animal must have rapidity and ease of motion on the ground: which qualities are secured by the length of the extremities; and in accordance with the extremities, are the elongated neck and lightly-formed head. Here, then, is the skeleton of an animal, properly terrestrial; it is accommodated to other peculiarities of its organisation connected with its living on arid plains; and is admirably adapted for a rapid and long-continued course. The hippopotamus, on the other hand, seeks its safety in the water; and its uncouth form and weight are suited to that element.

Of the Horse's Head.—It is perhaps better to draw our arguments from what is familiar and constantly before us: let us then take the form of the horse's head. Some have affirmed that the sound of neighing is produced in two sets of membranous chambers in the horse's head, called the Eustachian cavities. That name has been given to these cavities, because they communicate with the tubes termed Eustachian tubes, which lead from the throat to the ear. But that is a very unsatisfactory account of the cavities in question. We are of opinion that their use is connected with the weight of the head, the length of the neck, and the power of mastication of the animal. It is a very remarkable circumstance that a horse, whose "points" are approved of by the jockey, will starve in a grass field. By a system of crossing, the breeder will contrive, in a manner almost artificial, to combine the incidental defects of nature, so as to make the proportions of a horse correspond with his own ideas of perfection; and as a notion prevails that a short neck and small head are excellences, inasmuch as the weight upon the fore-feet is thereby diminished, it has sometimes happened that the neck has become too short; so that the animal has actually been unable to reach the ground, in grazing. Having observed that splints, corns, sandcracks, whitters, inflammations, and other diseases of the horse's foot, belong almost exclusively to the anterior extremity, they have attributed these to the weight of the head and neck, in conjunction with the artificial

condition of the horse: for were it, they say, the shoeing and hard roads alone that produced these bad effects, they would have been equally perceptible in the hind-feet. Such considerations tend to show the importance of the peculiarity now to be pointed out in the horse's skull.

On looking to the horse's head in profile, we see that its peculiar form, especially the great depth of its jaws posteriorly, is a necessary consequence of the length of the grinding teeth. We have already noticed the magnitude and weight of the elephant's head, in correspondence with its enormous teeth, provided for the attrition of its food: and if we apply the same rule to the head of the horse, we shall see how curiously it accounts for the peculiar shape of the skull. Like the elephant, the horse is graminivorous; and the structure of the teeth evinces how well calculated they are for mastication, without wearing. To enable the teeth to bear great pressure, they are socketed very deeply in the jaw; and as the strength of the muscles of mastication is applied not merely to close the jaws, as in the carnivorous animal, but to grind, or to rub the teeth both laterally and to and fro, extraordinary space is provided in the jaws, for the lodgement of the powerful muscle called masseter; a muscle which has the double action of closing the teeth, and of drawing the lower jaw across the upper. Here, then, we have the reason for that great square portion of the jaw, under the ear, which peculiarly distinguishes the horse's head: the bone is large, so as to give both a deep socketing to the molar teeth, and an extensive attachment to the muscles. Now, although the maxillary and nasal cavities in the horse are very capacious, yet the space which they take up does not suffice to occupy the remarkable depth of the lower jaw. In fact, the larynx and pharynx, the organs contained in that space, cannot fill up the whole depth of the head at this part; there is a great deal of room in the skull neither required for the lodgement of the brain, nor for the bony cavities of the nose, nor for the pharynx, nor the larynx; but solely resulting from the great size of the jaws. Had this space been occupied by solid bone, it would have added materially to the weight of the head. Accordingly it has been filled up by the two great membranous cells, the Eustachian cavities; which receive air into them by communicating with the cavities of the nose. On the whole, then, we may consider these large cells in

the horse's head, as permitting the enlargement of the jaw-bone at its back part, so as to afford a deep socketing for the grinding teeth, and a sufficient lodgement for the powerful muscles employed in mastication, without increasing very considerably the solid material of the head. As in birds, advantage is here taken of the admission of air, to increase the volume and strength of the parts, without adding to the weight. We now perceive that, if the horse's skull had been formed without these membranous air-cells, there would have been a positive defect, especially in the running horse; for the head would have greatly exceeded in weight; the animal would not have been properly balanced upon its extremities; and the weight upon the fore-feet would have been so much increased, as to have rendered him still more liable to those diseases of the foot to which his artificial condition subjects him.

This provision for making the head of the horse lighter, has a parallel in the head of the spermaceti whale. The spermaceti whale, a species of the physeter or cachelot, has a very large head; it is remarkable also for possessing teeth; the common whale having only whalebone in its mouth for teeth. Now, from the great size and length of the head, loaded as it is with teeth and jaw-bones, ponderous and dense in proportion, and from the lungs being situated too far behind the centre of gravity, it would have followed that the animal could not raise itself to the surface of the sea, for breathing: accordingly, large cavities in the head (twelve feet long, and four feet deep) are filled with spermaceti, a material lighter than water; by this means the head is rendered buoyant, and the equilibrium of the animal is maintained.

Although the changes in the shape of the skulls of animals principally affect their anterior part, that is, the bones of the face, yet the slighter deviations behind, if minutely scanned, may indicate much. For example, among other interesting specimens of fossil bones, the portion of a skull was found in the caves of the limestone rock near Plymouth. It consisted merely of the condyles or articulating processes of the skull, which join it to the vertebræ of the neck; together with parts of the occipital and temporal bones. Yet from that alone it could be ascertained that the fragment belonged to an hyæna: although its proportions were double those of the corresponding

parts of the largest recent species. First, the high spine indicated great muscular power in the neck; secondly, the depth and extent of the fossa or hollow for the lodgement of the temporal muscle, proved that there was a remarkable mass, and consequent strength of muscle, for closing the jaws; thirdly, that the fragment belonged neither to the bear nor the tiger, was shown by the extraordinary thickness and density of the whole bone. In this last respect, the portion of bone corresponded with that of no animal but the hyæna; for the entire skull of the hyæna participates in the strength which belongs so remarkably to its teeth; these being capable of breaking the hardest and largest bones.*

In treating of the jaw-bones and teeth of the hyæna found in a fossil state, Dr Buckland has given us an example of the mode of drawing deductions from such a subject, not inferior to the best specimen of similar reasoning by Cuvier. While lecturing on the comparative anatomy of the skeleton, I have put the subject in this light:—"All nature, we have seen, is full of life; and wherever food is to be obtained, there animals are, suited in structure to reach it. Suppose the horse run down by wolves, and his carcass consumed by lesser carnivorous quadrupeds, and birds of prey; there is still left, in the large cylindrical bones, an abundance of nutriment; which, however, these animals cannot get at. Turn your attention, then, to the skull of the hyæna; it presents great clumsiness and weight, contrasted with that of the dog, the wolf, or the bear. Next, observe the teeth; you see that they are conical—which is the very form of strength; and that by their abundant enamel, they are case-hardened on the exterior. In proportion to the power of resistance of the teeth, are the size and density of the jaws. Again, this hollow for lodging the temporal muscle, which closes the jaws; and this prominence of the zygomatic arch, which gives attachment to another muscle of the same class, produce together that extraordinary breadth of the face which is characteristic of this very ugly animal. And, corresponding with the strength of its teeth, jaws, and muscles, you see how much thicker and denser in its texture the whole skull is, than in other animals: as if to show, by the supporting frame-work

* This specimen is in the Museum of the College of Surgeons, and is beautifully drawn in Mr Clift's paper in the Philosophical Transactions.

the strength of the engine; an engine capable of breaking these powerful cylindrical bones of the larger animals, and of disclosing a rich repast in the marrow they contain."

[OF THE SPINE.—As the skull thus exhibits a freedom in changing its form, when required by its application to new offices, so it is with the spine; which, according to the theory we are considering, is still more centrally placed than the skull. It is true that the spine presents a general uniformity of shape and appearance. As the spinal marrow belongs to the whole class of vertebrated animals, and must be protected by the bony canal which we call the spine, the principal use of the part being permanent, so also must its form be permanent. But whenever there is a change in the action, or rather the play of the spine, we find the vertebræ conforming to that action.

Thus the progress of a fish through the water, results mainly from lateral movements of the spine and of the tail. Now, were the constituent bones formed like those of other vertebrata, the processes on each side would lock together, and interfere with these motions; they are, therefore, kept subordinate; while other processes, required to give varied and extensive origin to the numerous muscles, are elongated in a more remarkable and diversified manner than is to be found in any other animals. In the whale, dolphin, &c., the position of the tail differs from that in the fish: its flat surface is placed horizontally instead of vertically, which is to accommodate it to the important function of respiration; for these inhabitants of the sea must rise to the surface to breathe the air, and their tails are thus directed to enable them to elevate the head above the water.

In quadrupeds, the tail is the prolongation of the spine; and here the advocates of the theory think they have a strong case. Because the bones constituting the tail become smaller and rounder towards the end, and terminate in cartilage, in which there is no bone, it is thought to confirm the law—that parts, when repeated, become more and more imperfect as they recede from the centre. But is it not obvious that the tail is constructed with a view to its proper purpose: firm towards the root, and large enough for the attachment of muscles which shall play it about in all directions; but less firm, and more lithe and elastic towards the end, for it to carry the brush? Can anything be better adapted for its peculiar uses? Would

it have been more perfect, if, instead of a series of round bones joined together, there had been a set of vertebræ, fully formed, with all their projecting processes? In short, shall we conceal from ourselves the admirable adaptation of this appendage to its various offices—sometimes used as a mantle to coil round the animal for warmth—sometimes as a rudder in running—sometimes as a fan or switch, reaching where neither the ear nor the tongue can touch—all to favour an hypothesis of animal bodies being constituted so imperfectly that if a part, like a vertebra, be formed in the centre, and be repeated or prolonged, each link, as it recedes, becomes less and less perfect, degenerating from what is gratuitously assumed to be its original form?

The spine is the most perfect structure in the whole animal machine. Perhaps, if our words were critically taken, it would be better to say, that the intention of the curious mechanical structure was here the most apparent, and on that account, most the object of our admiration. Besides binding the bones of the skeleton together, and forming, as it were, the very centre of the whole, the spine is a tube, for protecting the most vital organ of all—the spinal marrow. But, again, in man, the spine has a new office imposed upon it; in correspondence with his privilege of carrying himself erect, it is a pillar for sustaining, not only the superior parts of the body, but the globe of the head, which we shall find it protects in a very unexpected manner. Our admiration, then, arises from being able to perceive the modes by which these different offices are performed by the construction of this column: how nature has reconciled the most opposite and inconsistent functions in one set of bones;—for the vertebræ are so strong, as not to suffer under the longest fatigue or the greatest weight which the limbs can bear; and so flexible, as to perform the chief turnings and bendings of the body; and yet so steady withal, as to contain and defend the most material and the most delicate part of the nervous system.

In some animals, the lowest of the vertebrata, the protecting texture of the spinal marrow hardly deserves the name of vertebral column. In certain fishes—for example, the myxine, lamprey, sturgeon, &c.—the spine consists of a cartilage, made tough by ligamentous intertexture. In the myxine, this cartilage does not entirely enclose the spinal marrow; for it lies in a deep groove on the upper part of the spine. But let us not suppose

that in fishes there is any imperfection in the vertebral column: it is an elastic structure on which the muscles act so as to become the means of powerful locomotion; and in all fishes the spine has, more or less, this remarkable elasticity. Ascending in the scale of animals, we find the cartilage forming the spinal column subdivided by cavities, which contain a gelatinous fluid; and these cavities being surrounded with a strong but elastic ligamentous covering, nothing can be conceived more admirably adapted to give a springiness to the whole column. Still ascending, we discover that the bony matter becomes deposited between these cavities; and here the separate vertebræ first appear. If two vertebræ of the great shark be taken out together, and the sac between them punctured, such is the elasticity of the walls of this sac, that the fluid will be spouted out to a distance. In other fishes, as the cod-fish, (an osseous fish,) the structure approaches to that of the mammalia; the intervertebral substance is gelatinous. In the whales, circular concentric ligaments join the vertebræ, and a small portion in the centre consists of a glairy matter. In mammalia, and in man, there are strong and distinct bones—the vertebræ; and these are joined by a ligamentous cartilage, the outer circle of which is remarkably strong, and the central soft and elastic. The toughness and strength of the exterior circle, and the soft condition of the centre, make a joint equivalent in action to what might be produced by a ball intervening between the surfaces: a facility of motion is thus bestowed which no form of solid could give; and yet the joint is so strong, that the bone breaks from violence, but the ligamentous cartilage never gives way. When the veterinary surgeon casts a horse, if he be not careful to restrain him, he will twist himself with a force which will break the vertebræ: fracture is a frequent accident in man; but the texture that gives mobility to the spine never yields.

The next thing admirable in the spine is the manner in which the head is sustained on an elastic column, whereby the brain is saved from undue concussion in the movements of the body. This object is not attained altogether through the elastic substance which we have described as intervening between the bones; it is owing, in a great measure, to the general form of the spine in man. Had the vertebræ been built up, like a lofty column, of portions, put correctly and vertically over one another,

the spine would not have had the advantages which result from the structure we are about to describe. The incumbent weight would then have fallen on the centres of all the bodies of the vertebræ; and they would have yielded but to a slight degree. The column is formed according to the figure of the italic *ſ*; which waving line we need not admire because it is the line of beauty, as some have defined it, but because it is the form of elasticity. The spine being originally of this curved shape, the pressure is directed upon the margins of the vertebræ and of the intervertebral substances; they therefore yield readily; by yielding, they produce an increase of the curve, and a consequent shortening of the whole column; and then they admit of an easy return to their original places. Suppose we rest the palm of the hand upon a walking-cane, elastic, but perfectly straight; it bears a considerable pressure without yielding, and when it does yield, it is with a jerk; but if it be previously bent, however we may increase or diminish the pressure, there will be no shock: the hand will be supported, or the cane yield, with an easy and uninterrupted resiliency. Such we conceive to be the end obtained through the double curvature of the spine: that the brain shall receive no shock, in the sudden motions of the body.

Were we to give our attention to the processes of bone which stand out from the bodies of the vertebræ, we should find unexpected provisions there also. It is a common remark of anatomists, that the bones of the spine are secured in their proper places, by the relations of the surfaces in contact; the surface of the body of the vertebra being oblique in one direction, and those of the articulating processes in another—the one inclination prevents the bone being dislocated forwards, and the other prevents it being displaced backwards. There is something more than this. The articulating processes consist of four wedge-like projections from the back and lateral parts of each vertebra; two being directed upwards, and two downwards; and their smooth surfaces are inclined in such a manner that those of the adjoining vertebræ slide upon one another—that is to say, the surface of the lower articulating process of the vertebra above, being itself inclined, moves upon another, viz., that of the upper articulating process of the vertebra below, which is also inclined. As the intervertebral substances of the bodies

yield and recoil, the articulating process of the upper vertebra shifts upon the inclined surface of the process on which it is seated, ascending and descending; but owing to the wedge-like shape of the processes, the impediment to the descent is greater the more the vertebra sinks; thus adding to the elasticity and security of the whole, and preventing the abrupt shocks which would be the consequence of the surfaces being horizontal. The eighteen-pounder made to recoil upon an ascending plane, or a surface forming a portion of a circle, represents the mechanism of the articulating processes of the vertebræ.

Let the separate spine be presented before us; it stands up, like a mast, broad and strong below, and tapering upwards. The mast of a ship is supported by the shrouds and stays; and if we sought for analogies to these, we must select the long muscles of the back which run along the spine to sustain it. But as a mast goes by the board in a storm, we see where the spine would be most in danger, if nature had not provided against it. When we start forward in walking or running, it is by the exertion of the muscles of the lower extremities; and the body follows. Did the spine stand directly up, perpendicularly, it would sustain a shock or jar at its base, in these sudden motions. We see, therefore, the intention of the lower vertebræ being inclined forwards from their foundation on the sacrum: for by this arching forwards, the jar which might endanger the junction of the lowest piece, is divided amongst the five pieces that form the curve. The same thing is seen in the neck of the quadruped; for as the spine in the back and loins lies horizontally, and the neck rises towards the perpendicular, there would be danger of dislocation, if the vertebræ of the neck rose suddenly and abruptly upwards from the body: there is, therefore, at the lowest part of the neck, a sweep or semicircle formed by several vertebræ, to permit the head to be erected; a remarkable example of which is shown in the stag.*

* Every one who has seen a ship pitching in a heavy sea, must have asked himself why the masts are not upright, or rather, why the fore-mast stands upright, whilst the main and mizen masts stand oblique to the deck, or, as the phrase is, rake aft or towards the stern of the ship. The main and mizen masts incline backwards, because the strain is greatest in the forward pitch of the vessel; for the mast having received an impulse forwards, it is suddenly checked as the head of the ship rises; but the mast being set with an inclination backwards, the motion falls more in the perpendicular line from the head to the keel. This ad-

It may be here observed, that when a delicate piece of mechanism is constructed by the hands of man, it may be put aside, locked up, and preserved. But the most delicate textures of the living frame stand distinguished above all by this quality—that if they be not put to use, they very quickly degenerate. Not only is the power of action lost by inaction; as every one must be aware in the functions of his own mind, or in the exercise of his senses; but the texture of the organs quickly deteriorates. If by accident a limb should lose certain movements, the muscles, nerves, vessels, which nature intended to be subservient to these motions, become, in a few weeks or months, so wasted, that they are hardly recognisable by the anatomist. Applying this acknowledged principle to the spine, and bearing in mind that the texture of bone, cartilage, ligament, tendon, muscle, in short, all the parts which enter into its structure, however varying in solidity or composition, retain their perfection by being exercised, we shall readily perceive the effect of undue confinement on young females. Without any positive disease, but from being over-educated in modes which require sedentary application, the spine becomes weak, and loose in texture, and yields to the prevailing posture, whatever that may be. We mention this, because it is a principle important in every consideration to each individual, and applicable to both body and mind.

Of the Chest.—The thorax, or chest, is formed of bones and cartilages, so disposed as to sustain and protect the most vital parts, the heart and lungs; to move incessantly in the act of respiration, without a moment's interval during a whole life; and to turn and twist with perfect facility, in every motion of the body. In anatomical description, the thorax is formed of the vertebral column, or spine, on the back part; the ribs on either side; and the breast-bone, or sternum, on the fore part. The manner in which these bones are united; and especially, in which they are joined to the breast-bone by the interposition

vantage is lost in the upright position of the fore-mast, but it is sacrificed to a superior advantage gained in working the ship; the sails upon this mast act more powerfully in swaying the vessel round, and the perpendicular position causes the ship to tack or stay better; but the perpendicular position, as we have seen, causes the strain in pitching to come at right angles to the mast, and is, therefore, more apt to spring it. These considerations give an interest to the fact, that the human spine, from its utmost convexity near its base, inclines backwards.

of cartilages, or gristle, a substance softer than bone, and more elastic and yielding; is most admirable. By this combination of hardness and elasticity, the ribs are fitted to protect the chest against the effects of violence; and even to sustain life, after the muscular power of respiration has become too feeble to continue, without the aid of elasticity.

If the ribs were complete circles, formed entirely of bone from the spine to the breast-bone, there would be greater liability to fracture and danger to life; the rubs and jolts to which the human frame is continually exposed, would be too much for their delicate and brittle texture. This evil is avoided by the interposition of the elastic cartilages. On their fore part, the ribs are eked out and joined to the breast-bone by means of cartilages of a form corresponding to their own; being, as it were, the continuations of the arches of the ribs by substances more adapted to yield, and recoil, in every shock or contusion, than bony hoops. The elasticity of this portion meets and subdues those crushings of the body which would otherwise occasion fracture of the ribs. We lean forward, or to one side, and the ribs accommodate themselves, not by a change of form in the bones, but by the bending or elasticity of the cartilages. A severe blow upon the ribs does not break them, because their extremities recoil and yield to the violence. But it is only in youth, when the human frame is in perfection, that this pliancy and elasticity have full effect. In old age, the cartilages of the ribs become bony; they are firmly attached to the breast-bone, and the extremities of the ribs are fixed, as if the whole arch were formed of bone, unyielding and inelastic. Then a violent blow upon the side will fracture the ribs,—an accident seldom occurring in childhood, or in youth.

There is a purpose still more important to be accomplished by means of the elastic structure of the ribs; that is, in the highly excited respiration which accompanies great efforts of bodily strength. There are two acts of breathing—*expiration*, or the sending forth of the breath; and *inspiration*, or drawing in the breath. When the chest is at rest, it is neither in a state of expiration, nor in that of inspiration; it is in the intermediate condition; and the muscular effort by which either the one or the other is produced, is an act opposed to the elasticity of the ribs. The muscles of respiration are excited alternately, to

dilate or to contract the cavity of the chest, and, in doing so, to raise or depress the ribs. Hence it is, that both in inspiration and in expiration, the elasticity of the ribs is called into play; and, were it within our province, it would be easy to show, that after the muscular power had become too weak to continue the breathing unassisted, the action can be carried on, and life preserved, through the aid of the elastic property of the ribs.

From what has been now explained, it will at once be understood that violent exertion is incompatible with the condition of the chest in old age. The elasticity of the cartilages is gone, the circle of the ribs is unyielding, and will not allow that high breathing, that sudden and great dilatation and contraction of the cavity of the chest, which is required for circulating the blood through the lungs, and relieving the heart in the tumultuous flowing of the blood which laborious exertion produces.

Looking to the means of guarding life, nothing can be more important than the condition of the lungs in respect to the quantity of atmospheric air within them. The sensibility, and the rapid contraction of the glottis, near the mouth of the respiratory tube, are for arresting any foreign matter, afloat in the atmosphere, which might be drawn in by the stream of inspired air, and so reach the recesses of the lungs. But were this all, the office would not be half performed. The foreign body would be arrested; but how expelled, if it lodged? In common expiration, the air is never discharged altogether from the lungs; there is enough retained to be propelled against this foreign body, and to eject it. And, but for this, the sensibility of the glottis, and the actions of the expiratory muscles, would be in vain; we should be suffocated by the slightest husk of seed, or subject to deep inflammation from foreign matter drawn into the air-tubes collecting in the lungs.

We may here observe, that the instinctive actions for the protection of the body are calculated, if we may say so, for the natural condition of man. The manufacturer is sometimes removed from that condition; and our invention must be taxed, not only to maintain the purity, in a chemical sense, of the atmosphere in which he works, but to arrest, or convey away, the small portions of material which may be thrown off—for example, by the operations of the flax-dresser in heckling, or of the cutler who grinds the steel after the instrument is

forged, or of the stone-cutter, &c.—and so to prevent those particles from being inhaled. The length of the air-passages which lead to the lungs, the sensibility and muscular apparatus bestowed upon them, and the mucous secretions thrown into them, are the natural means by which foreign matter is arrested and thrown out. But in these artificial conditions of men, insoluble particles are continually floating in the atmosphere which they breathe; these are drawn in and lodge in the lungs, and irritate to disease.

This part of our subject suggests the consideration of that law of fluids which appears, at first, so contradictory as to be called the "hydrostatic paradox." Suppose a machine formed of two boards of equal diameter, and joined together by leather nailed to their margins, like a pair of bellows; a hole is made in the upper board, into which is inserted a tube. If a person mount upon this apparatus when it is filled with water, and blow into the pipe, he can raise the upper board, carrying himself upwards by the force of his own breath—indeed, by the power of his cheeks alone. It is on the same principle that, when a forcing-pump is let into a closed reservoir of water, it produces surprising effects. The piston of the hydraulic press being loaded with a weight of one pound, the same degree of pressure will be transmitted to every part of the surface of the reservoir that is given to the bottom of the tube, and the power of raising the upper lid will be multiplied in the proportion that its surface is larger than the diameter of the tube. Or, to state it conversely: suppose we had to raise the column of water in the tube by compressing the reservoir; it would require the weight of a pound on every portion of the superficies of the reservoir equal in extent to the base of the piston, before the water could be raised in the tube. Were the apparatus which we have described full of air instead of water, we should witness a similar effect; for all fluids, whether elastic or not, press *equally in all directions; and this is the law on which the* phenomenon depends. If we blow into the nozzle of a common pair of bellows, it is surprising what a weight of books we can heave up if laid upon its board.

Understanding, then, that the power of the hydraulic press, in raising the lid, depends on the size of the reservoir, and its relation to the tube; and again, that in pressing the fluid up

through the tube, the pressure upon the sides of the reservoir must be the greater the larger the cavity, we can conceive how a glass-blower propels the air into his blow-pipe with great ease, if he blow by means of the contraction of the cheeks, the smaller cavity; but that it will be with an exhausting effort, if he blow by the compression of the larger cavity, the chest. Dr Young made a calculation that, in propelling the air through a tube of the same calibre, a weight of four pounds, operating upon a cavity of the size of the mouth, would be equal to the weight of seventy pounds, pressing upon a cavity of the dimensions of the chest.

Let us see how beautifully this hydraulic principle is introduced to give strength in the common actions of the body. We have remarked that the extension of the superficies of the thorax is necessary to the powerful action of the muscles which lie upon it; and these are the muscles of the arms. In preparation for a great effort, we draw the breath and expand the chest. The start of surprise, and of readiness for exertion, in man and animals, is this instinctive act. But unless there were other means of preserving the lungs distended, the action of those muscles which should be thrown upon the arms would be wasted in keeping the chest expanded. It is here, then, that the principle which we have noticed is brought into play. The chink of the glottis, which the reader has already understood to be the top of that tube which descends into the lungs, is closed by a muscle not weighing a thousandth part of the muscles which clothe the chest; yet this little muscle controls them all! A sailor leaning his breast over a yard-arm, and exerting every muscle on the rigging, gives a direction to the whole muscular system, and applies the muscles of respiration to the motions of the trunk and arm, through the influence of this small muscle, that is not capable of raising a thousandth part of the weight of his body; because this little muscle operates upon the chink of the glottis, and is capable of opposing the whole combined power of all the muscles of expiration. It closes the tube just in the same way that the man standing on the hydraulic bellows can with his lips support his whole weight. Thus it is that the muscles which would else be engaged in dilating the chest, are permitted to give their power to the motions of the arms.

Some cruel experiments have been made, which, for whatever intended, illustrate the necessity of closing the top of the wind-pipe during exertion. The wind-pipe of a dog was opened, which produced no defect until the animal was solicited by his master to leap across a ditch, when it fell into the water in the act of leaping; it failed in its leap, because the muscles which should have given force to the fore-legs lost their power by the sudden sinking of the chest. This experiment is sufficiently repugnant to our feelings; and I need not offend the reader by giving instances in further illustration, from what sometimes takes place in man.]

RELATION BETWEEN THE SKELETON OF THE BIRD, AND ITS MODE OF PRODUCING ITS OFFSPRING.—Having, in the earlier part of the volume, noticed some of the more remarkable peculiarities of the skeleton of the bird, we may take this opportunity of observing the relation between its general form, and one of its principal functions. Putting out of the question, for the present, digestion and respiration, functions necessary for preserving the life of the individual, the continuation of the species is the next in importance. If a bird is to be buoyant and capable of flying, it cannot be viviparous. We have seen that a full stomach impeded the flight of a carnivorous bird; now, from that it is evident that it could not have carried its young within it. Is it not curiously provided, then, that the bird shall produce its offspring by a succession of small eggs; and that these shall accumulate in the nest, instead of growing in the body? In short, it requires no argument to prove that the hollow bones of the skeleton, the extension of the breast-bone, the air-cells, the quill-feathers, the bill, and the laying of eggs, are all in necessary relation to each other.

OF THE KANGAROO.—Since we have spoken of the adaptation of the skeleton of the bird to its mode of producing its young, we may, for the same object, advert to the subject in a quadruped. In the *mammalia*, there is no deviation from the general form of the skeleton more extraordinary than that in the kangaroo; and there is, at the same time, a remarkable peculiarity in the manner in which it produces its offspring. Instead of remaining within the mother for the usual period of gestation, the young, by a singular process, not perfectly understood, is excluded, and found attached to the teat there, covered by an

exterior warm pouch, formed of the skin; it hangs by the mouth, until, from being a minute and shapeless thing, it is matured to the degree when the offspring of other animals are usually brought forth.

Now it appears that the upright position of this animal, and the disproportioned magnitude of the lower part of its body—for it is the only creature except man which rests in the perpendicular—may account for the peculiarity of its mode of gestation. Without entering far into the subject, we may observe that an accurate correspondence must subsist between the form of the young offspring and the bones of the mother through which it has to be expelled. In animals generally, the head is the larger part; but in the kangaroo, that bears no proportion to the magnitude of the hind quarters; for when an animal is designed for the perpendicular position, the hip-bones must necessarily be of large size to sustain the weight; and such is the case with the kangaroo. Nature has, therefore, accomplished the production of the young safely, and by the simplest means,—that is, by anticipating the period of the separation of the young animal; and providing for its growth exteriorly, after it has passed through the circle of bones called the pelvis. For these reasons we conclude that there is a relation between the mode of producing the offspring, and the form of the skeleton, in this animal.

I hope that I have now gone far enough to prove that where uniformity is preserved in the shape of any part of the skeleton, it depends on the permanence in the function of the organ. In certain respects the head and spine are persistent in their forms; but that is merely because the brain and spinal marrow contained within the skull and vertebral column do not vary, except in point of relative size. As regards the application of the bones of the face to be instruments for obtaining food, for attack, or defence, they are ever curiously changed in their processes and articulations, in accommodation to the numerous different modes of using the parts. In fine, we may observe, that there never takes place any modification in the form of the parts of the body,—whether in the forehead, occiput, jaws, teeth, spine, pelvis, or extremities,—without a corresponding adaptation extending through the whole skeleton.

IMAGINARY ANIMALS.—"No doubt we can imagine a greater variety of animals than do actually exist;" such are the words of Archdeacon Paley. But what is the fact? Suppose we take the fabled animals of antiquity; not one of them could have existed!

It may serve both to show the imperfection of man's ingenuity, compared with nature, and the perfection of the system of the animal body, if, for a moment, we examine these imaginary animals, and inquire whether they could have fed, or breathed, or moved, or flown.

What, in fact, are these monstrous fancies, but an incongruous union of parts of different animals, patched together without order or system, and which could not have belonged to any living creature? When the head of a lion is joined to the belly of a goat, or the head of a woman to the body of a bird, or the body of a man to the tail of a serpent, there is no real invention. Not one of the centaurs of Thessaly, satyrs of the Indian mountains, sphinxes of Egypt, griffins among the one-eyed nations, could have stood, run, or flown. It may be alleged, and perhaps truly, that these figures were mere allusive representations—the mystical types of some country or element. It is sufficient, however, for our argument, that such are the only imaginary animals which have been acquiesced in by the classical scholar, as having had a fanciful existence.

In the antique marble figure of the centaur, the merit of the sculptor is evinced by his success in reconciling our fancy to the unnatural union of the various members: for example, in the face, the expansion of the nostrils, and the coltish wildness of the expression, are in correct correspondence with the artist's design of joining to the human form that of the horse. But this attempt at combined representation would not have satisfied one narrowly acquainted with the proportions of the horse. He would know that too heavy a fore-quarter, too long a neck, or too large a head, was incompatible with wind, speed, or safe going; and he would have concluded that an animal with such defects would be unsound, would founder in the feet. What, then, would he have said to a centaur, where, besides head and extremities, an additional body is made to rest upon the fore-legs?

Galen wonders if Pindar believed in centaurs. "For," says he, "if such an animal were to exist, it ought to have two mouths; one to correspond to the stomach of man; the other

to masticate for the stomach of the horse. If it could run upon the plain, it could not climb the hill, or make its way in rocky places. Though possessed of human faculties, it could not build for itself an habitation, or navigate ships, or man the sails;" and, more particular still in his objections, he adds, "that it could neither sit like the tailor, nor make shoes like the cobbler."

How nature manages to rear a heavy structure on the fore-legs of a quadruped, without the incumbent weight bearing inordinately upon them, we saw when examining the skeleton of the giraffe. We observed that the pressure of the greatly elongated neck was partly taken off the fore-quarters, and directed on the hind-legs by the oblique position of the spine and shortness of the hind-quarters. However beautiful, then, as works of art, may be the figures of the centaur upon antique gems, they are yet monsters; their construction, a joining together of incongruous parts.

Few designs are more difficult to execute than that of the fawn or satyr. This results from the artist having to reconcile the inconsistencies of a human form and face united to the limbs of a brute. If we have attended to the great size and strength of the human lower extremities, as compared with the upper part of the body, we may have perceived the incongruity of rearing the human trunk and head upon the hind-legs of a goat, the bones of which are disproportionately small, and the masses of muscle misplaced. This is not thought of by the painter and sculptor, when they represent their fawns dancing and piping. An instant's consideration of the comparative size and relative position of the bones, and of the action of the muscles, would have shown that the limbs must have been incapable of such activity. Had these fabulous forms actually existed, they must have crept weakly along the ground.

And so of the griffin. Eagle's wings could never have raised the body of the lion. For a creature to rise on the wing, there must be not only a mass of muscle proportioned to the extended wing, but a surface of bone of sufficient extent to give lodgment and attachment to the muscles of flight. Corresponding to the muscular strength of the lion, his bones are thick, dense, and heavy; now a skeleton composed of such bones would never answer for a creature that was to be buoyant in the air. Accordingly, even if the external forms were consistent, the internal conformation would be incompatible with the existence of

such an animal as the griffin. The lion's tail, again, would be a very useless appendage, compared with the fine rudder with which the eagle directs his swoop.

These instances might be multiplied. But we venture to say that every animal form, not actually existing in nature, but the invention of the artist or poet, would be discovered to have some defect in the balance of the exterior members, or in the relation of the parts necessary for motion; or were the exterior and moving parts duly balanced, some internal organ would be found unconformable, or displaced—too much developed, or too much compressed. In short, man's imagination is more limited than he may at first have believed. His inventions are only the incongruous union of things presented separately in nature. It is, indeed, far beyond his power to accomplish what was supposed possible by Paley, who said, "that multitudes of conformations, both of vegetables and animals, may be conceived capable of existence and succession, which yet do not exist."

This manner of viewing the subject confirms more strongly our belief in the perfection of that natural system of parts, which, in an infinite variety of creatures, admits of all the changes necessary for the different acts of walking, running, flying, swimming, &c.; at the same time that it accommodates the internal functions which minister to life, to every condition of existence to which the animal may be destined.

ƎENSIBILITIES INDUCE COMBINED MUSCU-
NS, FOR THE PROTECTION OF THE VITAL
THE PERFORMANCE OF THEIR FUNCTIONS.

ıe examples given in Chap. VII., we offer one show how the sensibilities, which are endow-ry and are adapted to the mechanical organisa-opriation more admirable than the mechanism. e allude to differs from that of the skin. It is n with numerous muscles; and without its r property of controlling, independently of the ed combinations of the muscles, the mechanical about to describe would be useless.

windpipe, the larynx, consists of five elastic e do not merely keep the sides of the windpipe sage for the breath free, but they perform to the economy both of body and mind; they part of the instrument of voice: they at the the lungs from injury.

rtilage is the largest; it is that which we feel fore part of the throat. Situated behind, nbrace of the thyroid, are the arytenoid carti-larly triangular form, socketed on the cricoid nd perfectly moveable. Between the corners cartilages, which project forwards, and the ched, from behind forwards, two ligaments, little distance from each other, called the vocal *les*); these ligaments or cords, being invested embrane of the windpipe, a slit, like the till

This is a subject far from being exhausted in our philosophical works; but at present we may look on these vocal cords, not as connected with voice, but in another of their offices, as forming the commissure which *opens and shuts in breathing to* protect the lungs from the intrusion of extraneous bodies. And here it is pertinent to remark, that in the structure of an animal body, one organ is frequently made subservient to several functions, and that without interference with the performance of any of them. This is especially true of the larynx. It is to one of its uses only that we have at present to attend.

The chink of the glottis formed between the cordæ vocales opens at every inspiration, and closes at every expiration, expanding and contracting as we see the nostrils do in breathing. But the admirable thing is the acute sensibility given to this part, and the immediate influence of that sensibility upon the muscles connected with it. As soon as the lightest husk, or seed, or smallest fly, drawn in with the breath, touches the margin of the chink, there is a rapid action of the muscles which move the vocal cords, the aperture is closed, and the object is arrested. This provision is an effectual means of preventing the entrance of foreign matters into the delicate cells of the lungs. But how is the object carried thus far expelled? The same sensibility of the aperture of the glottis animates another, and that a very extensive class of muscles, viz., all those which, seated on the chest, compress it, and force out the air, in coughing; these combining in one powerful and simultaneous effort, whilst the glottis is closed, overcome that constriction, and propel the breath through the contracted pipe with an explosive force, which brushes off the offending body.

There is one thing more necessary to this most important though familiar action. The lungs are never empty of air: in breathing, we do not fully expel it. If we did, there would be a period of danger occ

APPROPRIATE SENSIBILITIES INDUCE COMBINED MUSCULAR ACTIONS, FOR THE PROTECTION OF THE VITAL ORGANS, OR THE PERFORMANCE OF THEIR FUNCTIONS.

In addition to the examples given in Chap. VII., we offer one or two more, to show how the sensibilities, which are endowments of life, vary and are adapted to the mechanical organisation, with an appropriation more admirable than the mechanism. The sensibility we allude to differs from that of the skin. It is put in connection with numerous muscles; and without its high and peculiar property of controlling, independently of the will, the multiplied combinations of the muscles, the mechanical provisions we are about to describe would be useless.

The top of the windpipe, the larynx, consists of five elastic cartilages. These *do not merely keep the* sides of the windpipe apart, and a passage for the breath free, but they perform offices important to the economy both of body and mind; they are an essential part of the instrument of voice: they at the same time guard the lungs from injury.

The thyroid cartilage is the largest; it is that which we feel projecting on the fore part of the throat. Situated behind, and within the embrace of the thyroid, are the arytenoid cartilages, of an irregularly triangular form, socketed on the cricoid cartilage below, and perfectly moveable. Between the corners of the arytenoid cartilages, which project forwards, and the thyroid, are stretched, from behind forwards, two ligaments, parallel, and at a little distance from each other, called the vocal cords (*cordæ vocales*); these ligaments or cords, being invested with the lining membrane of the windpipe, a slit, like the till of a shop-counter, is formed between them; and through this chink (called *rima glottidis*) the air passes to and fro. To the sides and back part of the arytenoid cartilages small muscles are attached; and these, by moving the cartilages, tighten or relax the cordæ vocales; which, again, by vibrating in the stream of air, vocalise the breath, and the tones so produced are articulated in speech.

This is a subject far from being exhausted in our philosophical works; but at present we may look on these vocal cords, not as connected with voice, but in another of their offices, as forming the commissure which opens and shuts in breathing to protect the lungs from the intrusion of extraneous bodies. And here it is pertinent to remark, that in the structure of an animal body, one organ is frequently made subservient to several functions, and that without interference with the performance of any of them. This is especially true of the larynx. It is to one of its uses only that we have at present to attend.

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There is one thing more necessary to this most important though familiar action. The lungs are never empty of air: in breathing, we do not fully expel it. If we did, there would be a period of danger occurring seventeen times in a minute; for in the first part of each inspiration, something might be drawn into the windpipe which would suffocate: but by this reserve of air in the lungs, the act of coughing can take place at any instant and the object be expelled.

The sensibility seated in one spot of the throat, so beneficently, does not extend into the windpipe or lungs; for we cannot more admire the perfect adaptation of this property to its object, than

the fact of its never being bestowed in a superfluous degree, or given where it is not absolutely required. Just as we have seen that the sensibility of the skin suffices to protect the parts situated beneath, so the sensibility of the top of the windpipe protects all the interior of the tube and the lungs themselves, without extending through the whole continuous surface.

The simple act of sneezing affords a curious instance of the mutual relation between the muscular activity and the governing sensibility. The sensation which gives rise to this convulsive act, is seated in the membrane of the interior of the nostrils; we are not surprised, therefore, at its differing from the sensibility in the throat which excites coughing, the seat of both being different. But as regards the muscular action succeeding the irritation in the nostrils, is it not curious, that in the powerful expiration which constitutes sneezing, some twenty muscles or more, which had been excited in the similar act of coughing, are thrown out of action; while a different set, about equal in number, which had not acted in coughing, are called into action; the difference in the combination of the muscles being for the obvious purpose of directing the strong current of air, past the mouth, along the tubes of the nostrils? By no act of the will could the air be propelled so successfully through the nose, to the effect of brushing off the offensive and irritating particles from the membrane, as by this co-operation of the muscles, excited by the peculiar sensibility.

It is surely admirable to find in the Mouth so many faculties combining and consenting in action, each with its appropriate organisation, and each most curiously connected with other structures. Thus we have the power of mastication, of deglutition, of modulation of the voice, the senses of taste and of touch, concentrated in one apparently simple organ. Not to speak of other relations, can there be any better proof of design, than the effects of the excited sensibility of the tongue? No sooner have the gustatory points of the nerves been excited, than there is poured out into the mouth most abundantly, by four distinct tubes, the saliva; that fluid which facilitates mastication, and directly prepares the food for the action of the stomach. We presume that this fluid is chiefly useful in mastication, as the glands are large, and the fluid most abundant, in animals which chew the cud. In all, these glands are so disposed as to receive

gentle pressure from the motion of the jaw; so that, whilst their vascular apparatus is excited by the sensibilities of the tongue, *the fluid is urged from the ducts by the pressure of the jaw*, and the action of the muscles which move it. And however well we might imagine such a supply of fluid to assist deglutition, this is not all that is here done in preparation; for whilst the morsel is moved by tongue, and lips, and jaws, an appropriate fluid is collecting in what appear to be mere irregularities in the back part of the throat, but which are, in truth, so many receptacles, that, pointing towards the stomach, give out their contents as the morsel passes.

There is one curious circumstance which we may notice before quitting this subject. Eating seems always to be an act of the will, and attended with gratification. Yet it is well known that the operation of mastication, or what is very nearly the same, *may go on within the stomach, without any outward sign at least of pleasure.* The gizzard (with which we are most familiar in fowls, though found in the vegetable feeders of different classes of animals) is correctly enough described as an organ of mastication, in which an incessant and alternate action of opponent muscles takes place, like the motions of the jaws. In the stomach of the lobster, these are not merely the muscles of chewing, but the teeth also: so that it appears the function may be performed altogether internally and without the volition, and probably without the sensations that accompany the offices of the mouth. We mention this, as drawing the reader to comprehend that many organs may be in operation in the internal economy, without our consciousness.

Let us advert to the mode of swallowing by the crocodile, as an instance of the changes in the organisation which adapt an animal to new conditions. In terrestrial animals, the act of swallowing must be accommodated to the atmosphere; but if the creature live in water, and still breathes the air, the structure of the parts must be changed. The crocodile seizes its prey, and descends into the water with it. Its power of descending does not result, as in the fish, from compressing the air-bladder, but is owing, as we have shown, to a provision in its ribs and lungs. Unless the crocodile could expel the air from its lungs in a greater degree than the mammalia are capable of doing, it could not crawl upon the bottom, nor retain its place there

without continual exertion. There is in the mouth, as well as in the thorax and lungs, an adaptation to this mode of destroying its prey by carrying it under water. The crocodile has no lips; it lies on the shore basking with its mouth open and teeth exposed, so that flies light upon and crawl into its mouth. Against these the air tubes are protected, not by lips, or a sensibility of the mouth, but by an apparatus which separates the mouth from the throat and windpipe. This partition between the cavities is necessary when the animal seizes its prey: for as it plunges under the water with open mouth, the air tube must be protected against the ingress of the water. For that purpose, there is a transverse ridge, arising from the body of the bone of the tongue, which raises a duplicature of the membrane, so as to form a septum across the back part of the mouth below, whilst the curtain of the soft palate, hanging from above, meets the margin of the lower septum, and they form together a complete partition between the anterior and posterior cavities. Thus the animal is enabled to hold its prey in the open mouth, without admitting the water to the air passages.

Hunger and Thirst.—Hunger and thirst are in truth senses, although the seat or organ is not easily ascertained. The wants, and desires, and pains accompanying them resemble no other sensations. Like the senses, they are given as monitors and safeguards, at the same time that, like them, they are sources of gratification.

Hunger is defined to be a peculiar sensation experienced in the stomach from a deficiency of food. Such a definition does not greatly differ from the notions of those who referred the sense of hunger to the mechanical action of the surfaces of the stomach upon each other, or to a threatening of chemical action of the gastric juice on the stomach itself. But an empty stomach does not cause hunger. On the contrary, the time when the meal has passed the stomach is the best suited for exercise, and when there is the greatest alacrity of spirits. The beast of prey feeds at long intervals; the snake and other cold-blooded animals take food after intervals of days or weeks. A horse, on the contrary, is always feeding. His stomach, at most, contains about four gallons, yet throw before him a truss of tares or lucerne, and he will eat continually. The emptying of the stomach cannot therefore be the cause of hunger.

The natural appetite is a sensation related to the general condition of the system, and not simply referable to the state of the stomach; neither to its action, nor its emptiness, nor the acidity of its contents; nor in a starved creature will a full stomach satisfy the desire of food. Under the same impulse which makes us swallow, the ruminating animal draws the morsel from its own stomach.

Hunger is well illustrated by thirst. Suppose we take the definition of thirst—that it is a sense of dryness and constriction in the back part of the mouth and fauces—the moistening of these parts will not allay thirst after much fatigue or during fever. In making a long speech, if a man's mouth be parched, and the dryness merely from speaking, it will be relieved by moistening; but if it come from the feverish anxiety and excitement attending a public exhibition, his thirst will not be so assuaged. The question, as it regards thirst, was brought to a demonstration by the following circumstance. A man having a wound low down in his throat, was tortured with thirst; but no quantity of fluid passing through his mouth and gullet, and escaping by the wound, was found in any degree to quench his thirst.

Thirst, then, like hunger, has relation to the general condition of the animal system—to the necessity for fluid in the circulation. For this reason, a man dying from loss of blood suffers under intolerable thirst. In both thirst and hunger, the supply is obtained through the gratification of an appetite; and as to these appetites, it will be acknowledged that the pleasures resulting from them far exceed the pains. They gently solicit for the wants of the body: they are the perpetual motive and spring to action.

Breathing, as we have seen, is even more directly necessary to life than food; but to this we are differently admonished. An appetite implies intervals of satiety and indifference. The uninterrupted action of breathing could not be supported by a perpetual desire: we cannot imagine such an uniformity of sensation. The action of breathing has been made instinctive, while pain and the alarm of death are brought as the only adequate agents to control the irregularities of a function so necessary to life. Pain does here what desire and the solicitation of pleasure could not accomplish.

Of the SENSIBILITIES governing the actions of the STOMACH.—The examples recently given may introduce us to an acquaintance with those internal sensibilities which excite the actions of parts quite removed from the influence of the will; but the description of the organs themselves may be deemed unnecessary. Let us take the instance of the guard which nature has placed on the lower orifice of the stomach, to check the passage of aliments not easy of digestion, which the appetites of hunger and thirst may have tempted one to swallow. This lower orifice is encircled with a muscular ring, and the ring is in the keeping of a watchful guard. If we are employing the language of metaphor, it is of ancient use; for the Greeks called this orifice *pylorus*, signifying a porter.* And his office is this: when the stomach has received the food, it lies in the left extremity, or is slightly agitated there. When the digestive process is accomplished, the stomach urges the food towards the lower orifice. If the matter be bland and natural, it passes, and no sensation is experienced. But if crude and undigested matter be presented, opposition is offered to its passage; and a contention is begun which happily terminates in the food being thrown again to the left extremity of the stomach, to be submitted to a more perfect operation of the digestive power seated there. It is during this unnatural retrograde movement of the food, that men are made sensible of having a stomach. Yet the sensations, how unpleasant soever, are not to be regarded as a punishment; but rather as a call on reason to aid the instinctive powers, and to guard against disease, by preventing impure matters from being admitted into the portion of the intestinal canal which absorbs, and would thus carry those impurities into the blood to engender disease.

Here, then, is another example of a sensibility bestowed to guard us against external influences, when they threaten destruction to the framework; and to regulate the operations of internal parts too complicated and too remotely situated for the superintendence of reason.

Medical authors, without being empirics, seem occasionally, from the rules they lay down, to calculate on the ignorance of the community. They appear to ignore the sensations expe-

* The upper orifice was called by them *œsophagus*, as if it were the *purveyor*, from two words signifying, to bring food.

rienced in the stomach during the process of digestion: and yet no harm can be apprehended from giving a man confidence in the warnings which these impart, as to the functions being healthy or disturbed. We have the best proof of what we wish to inculcate in the action of the ruminating stomach. A cow swallows the gross herbage, and fills its large first stomach. When it chews the cud, the stomach, by its action, rolls up the grass into distinct pellets, or balls, with as much regard to its being returned into the mouth, as we do in masticating and rolling the morsel in preparation for swallowing. When the ball is brought into the mouth and chewed, it is again swallowed; but in descending into the lower part of the gullet, a muscle draws close the aperture by which it had passed into the large stomach in the first instance; it is now ushered into a second stomach, and so successively onwards to that stomach in which the digestion is performed. The curious muscular apparatus by which this is accomplished need not be described; but surely the sensibility which directs it, and which, although independent of the will, is yet so like an operation of reason in its results, presents a subject of just admiration.

The elastic structure of the camel's foot; the provision around its eyes for ridding them of offensive particles; the power of closing its nostrils against the clouds of sand; and its endurance of fatigue—would not enable it to pass the desert, unless there were provisions for the lodgment of water in its stomach, and unless this apparatus were animated by peculiar sensibilities. Accordingly, a muscular apparatus is provided for retaining the water in the cells of its stomach, only permitting it to ooze out according to the necessities of the animal; there is also a muscular band which pulls up the one or the other of the orifices of the different stomachs, to receive the food from the lower end of the gullet, according to its condition, whether to be deposited merely as in a store, or to be submitted to the operation of digestion. The surprising thing in all this is not so much the mechanical provision, as the governing sensibility. What, for example, should, in the first place, impel the grosser food, newly collected, into the first stomach? What, after rumination and mastication in the mouth, should carry that into the third stomach? And why should the water be carried into neither of these, but into the cells of the second stomach?

Yet, after all, this only brings us back to a sense of the operations in our own bodies. The act of swallowing,—the propulsion of the food into the gullet, the temporary closing of the windpipe by the epiglottis, the momentary relaxation of the diaphragm, fibres of which encircle the upper orifice of the stomach at such a time,—is just as surprising. The shutting of the larynx by the epiglottis is never deranged but by the interference of the will. If the individual attempt to speak, that is, to govern the parts by volition, when they should be left to these instinctive actions, or if terror, or some such mental excitement, prevail at the moment of swallowing, then the morsel may stick in the throat.

All this shows how perfect the operations of nature are, and how well it is provided that the vital motions should be withdrawn from the control of reason, and even of volition, and be subjected to a more uniform and certain law. But the point to which we would carry the reader is this,—that the human stomach, though not so complicated in its apparatus of macerating and digesting vats as in some of the lower animals, especially the herbivorous, is possessed of a no less wonderful degree of governing sensibility, which may be trusted to as surely as the precepts of the most skilful physiologist. We are told that we must not drink at meals, lest the fluid interfere with the operation of digestion. Of this there need be no apprehension. The stomach separates, and lets off with the most curious skill, all superfluous fluid through its orifice; while it retains the matter fit for digestion. It retains it in its left extremity, permitting the fluid to pass into the intestines, there to supply the other wants of the system, no less important than digestion. The veterinary professor, Coleman, ascertained that a pail of water passed through the stomach and intestines of a horse at the rate of ten feet in the minute, until it reached the larger bowel. Drinking at a stated period after meals, say an hour, is at variance with both appetite and reason. The digestion is then effectually interfered with; for what was solid has become a fluid (the *chyme*); this fluid is already in part assimilated; it has undergone the first of those changes which fit it ultimately to be the living blood: and the drink mixing with it must produce disturbance, and interrupt the work of assimilation.

Looking in this manner upon the very extraordinary properties of the stomach, we perceive how natural it was for physicians to give a name to the sensibility of which we have been speaking. The *Archeus* of Van Helmont, the *Anima* of Stahl, were the terms used to designate this nature, principle, or faculty, subordinate to and distinct from perception; a notion entertained, and more or less distinctly hinted at, by philosophers, from Pythagoras to John Hunter.

We now learn what is meant by organic and by animal sensibility. The first is that condition of the living organ which makes it sensible of an impression, on which it reacts, and performs its functions. It appears from what has preceded, that this sensibility may cause the blowing of a flower or the motion of a heart. The animal sensibility is indeed an improper term, because it would seem to imply that its opposite, organic sensibility, was not also animal; but it means that impression which is referred to the sensorium, where (when action is excited) perception and the effort of the will are intermediate agents between the sensation and the action or motion.

We may sum up the inquiry into sensibility and motion thus:—

1. The peculiar distinction of a living animal is, that its minute particles are undergoing a continual change or revolution under the influence of life. Philosophers have applied no term to these motions.

2. An organ possessed of an appropriate muscular texture, and of sensibility in accordance with the moving instrument, as the heart or the stomach, has the power of action without reference to the mind. The term *automatic*, sometimes given to those motions, conveys a wrong idea of the source of motion, as if, instead of being a living power, it were consequent upon some elastic or mechanical property.

3. There are sensibilities bestowed on certain organs, and holding a control over a number of muscles, which combine them in action in a manner greatly resembling the influence of the mind upon the body, yet independent of the mind; as the sensibility which combines the muscles in breathing.

4. In the last instance, a large class of muscles is combined without volition. But the whole animal fabric may be so employed; as in the instinctive operations of animals, where there is an impulse to certain actions not accompanied by intelligence.

5. A motive must exist before there are voluntary actions; and hence philosophers have supposed that there can be nothing but instinctive actions in a new-born child. But we must distinguish here what are perfect at first, from what are at first imperfect and irregular, and become perfect by use and the direction of the will. The act of swallowing is perfect from the beginning. The motions of the legs and arms, and the sounds of the voice, are irregular and weak, and imperfectly directed. It is the latter which improve with the mind. From not knowing the internal structure, and the arrangement of the nerves, philosophers, as Hartley, supposed that an instinctive motion, such as swallowing, may become a voluntary act. Volition in the act of swallowing consists merely in putting the morsel within the instinctive grasp of the fauces, when a series of involuntary actions commences, over which we have no more control in mature age than in the earliest infancy. Swallowing is not a voluntary action; the thrusting of the morsel back with the tongue is like the putting of the cup to the lip. It is the preparation for the act of swallowing that is voluntary: but over the act itself we have no control.

It is an error to suppose that all muscular actions are in the first instance involuntary, and that over some of them we acquire a voluntary power. A child's face has a great deal of motion in it, very diverting from its resemblance to expression, before there can be any real motive to the action. It will crow, and make strange sounds, before there is an attempt at speech. But this gradual development of intelligence and acquisition of power ought not to be called the will attaining influence over involuntary muscles, since, in fact, the apparatus of nerves and muscles is prepared, and waits for the direction of the mind with so perfect a readiness, as to fall into action and just combination before that condition or affection of the mind which should precede the action takes place. A child smiles before anything incongruous can enter the mind, before even pleasure can be supposed a condition of the mind. Indeed, the smile on an infant's face is first perceived in sleep.

6. All the motions enumerated above are spontaneous motions belonging to the internal economy; but the external relations of the animal, the necessity of escaping from injury or warding off violence, require a sensibility to those outward impressions,

and an activity consequent on volition. Nothing less than perceptions of the mind, and voluntary acts, suited to a thousand circumstances of relation, could preserve the higher classes of animals, and man above all others, from destruction.

All these provisions proceed from an arrangement of nerves and muscles. The mechanical adjustment of the muscles and tendons is perfect according to the principles of mechanics. The muscles themselves possess a different property; they are irritable parts; motion originates in them. This living property of contraction is admirably suited, in each particular muscle, to the office it has to perform. In some it is necessary that the muscles should act as rapidly as the bowstring on the arrow; in others their action is slow and regular; in others it is irregular, and after long intervals, according as the functions to which they are subservient require. The motions of the limbs, the motions of the eye, those of the heart and arteries, stomach and bowels, are all different. This appropriation of action is not in the muscles themselves, but as they stand in relation to the nervous system, and the sensibilities which impel them.

We hope, then, that by the course we have taken, we have carried the reader to a higher sense of the perfection of the animal structure. We first drew him to observe provisions in the strengthening of the bones, the adjustment of their extremities to the joints, the course of the tendons, and other such mechanical appliances; proving to him the existence of design in the formation of the solid fabric of the body. We have then explained how that motion is produced which was at all times familiar to him, but even the immediate causes of which he did not comprehend. We have, in the last place, shown him that under the term Life, he has a still more admirable subject of contemplation, in the adjustment of the living properties; in the sensibilities, which differ not so much in degree as in kind; and in their appropriation, both to the operations of the internal economy, and to the relations external and necessary to safety.

It is not possible to examine these things without having the full proofs before us of the power of the Creator in forming and sustaining the animal body. As a man with *gutta serena* may

turn his eyes to the sun, and feel no influence of light, so may the understanding be blind to these proofs. With the celebrated Dr Hunter, we may say, that he who can contemplate them without enthusiasm, must labour under a dead palsy in some part of his mind; and we must pity him as unfortunate.]

A COMPARISON OF THE EYE WITH THE HAND.

"And the eye cannot say unto the hand, I have no need of thee."

IF in quest of an object which shall excite the highest interest, and at the same time afford the most convincing proofs of design, we naturally turn to the Eye, as the most delicate of all the organs of the body. And some consideration of this organ is appropriate to our present purpose, which is to show how much the sense of vision depends on the Hand—how strict is the analogy between these two organs.

From the time of Sir Henry Wotton, to the latest writer on light, the eye has been a subject of admiration and eulogy. But on a former occasion,* I have ventured to say, that this admiration is misplaced, if given to the ball of the eye, or the optic nerve, exclusively. The high endowments of this organ belong to the exercise of the whole eye—to its exterior appendages of muscles, as much as to its humours and the proper nerve of vision. It is to the muscular apparatus which moves the eye, and to the conclusions we are enabled to draw from the consciousness of muscular effort, that, in combination with the impression on the retina, we owe our knowledge of the form, magnitude, and relations of objects. One might as well imagine that he understood the uses of a theodolite by estimating the optical powers of the glasses, without looking to the quadrant, level, or plumb-line, as suppose that he had learnt the whole powers of the eye by confining his study to the naked ball.

Let us begin by some observations on the minute structure, and the sensibility, of the retina. The retina is the internal coat of the eye; it consists of a delicate, pulpy, nervous matter, which is contained between two membranes of extreme fineness; and these membranes both support it and give to its surfaces a smoothness mathematically correct. The matter of the nerve, as well as these supporting membranes, is perfectly transparent during life. In the axis of the human eye, there is a small

* See Philosophical Transactions.

portion which, after death, when the rest of the membrane becomes opaque, remains transparent; and has thence been mistaken for an opening in the retina.* Surprising as it may be after all the industry employed to demonstrate the structure of the eye, it is only in the present day that a most essential part of the retina has been discovered—the membrane of Mr Jacob. From observing the phenomena of vision, and especially the extreme minuteness of the image cast upon the retina, I had conceived that the whole nerve was not the seat of vision, but only one or other of its surfaces. That could not be well demonstrated until this exterior membrane of the retina was known; now we see, when it is floated in water under a magnifying glass, that this membrane is of extreme tenuity: and its smooth surface is calculated to correspond to the exterior surface of that layer of nervous matter, which is the seat of the sense.

The term retina would imply that the nerve constituted a network; and the expressions of some of our first modern authorities would induce us to believe that they viewed its structure in that light, as agreeing with their hypothesis. But there is no fibrous texture in the matter of the nerve: although, when floated and torn with the point of a needle, the innermost of the membranes which support the retina, the *tunica vasculosa retinæ*, presents something of that appearance.

Vision is not excited by light, unless the rays penetrate through the transparent retina, and reach its exterior surface from within.

We all know that by pressing upon the eye-ball with a key or end of a pencil-case, zones of light are produced: and they are perceived as if the rays came in a direction opposite to the pressure. It may be said, that here the effect of the pressure is assimilated to that of light; and as light can approach and strike the part of the nerve pressed upon from without by the key, only by entering the interior of the eye and coming from within, that the zones of light produced by the mechanical impulse must appear in the usual direction of rays impinging upon that part: and that, consequently, they will give the impression of their source being in the opposite quarter. Contrast, however, this phenomenon with the following experiment. Let the eyelids be closed, and covered with a

* It is this part which is called the *foramen* of Soemmerring.

piece of black cloth or paper, with a small hole in it; place this hole, not opposite to the pupil, but to the white of the eye; then direct a beam of light upon the hole: this light will be seen in its true direction. Why is there this difference in the apparent place from which the light is derived in these two cases? Is it not because the rays directed through the hole upon the white part of the eye-ball, after penetrating the coats and striking upon the retina at this part, pierce through it, and through the *humours* of the eye, and impinge upon the retina again on the opposite side? That explains why light transmitted in such a manner shall appear to come from a different quarter. But it does not explain why there should not be a double impression—why the beam of light should not influence the retina while penetrating it in the first instance; that is, in passing through it from without inwards, as well as when it has penetrated the humours and impinged upon its opposite part, from within outwards.

Another fact, which has perplexed philosophers, is the insensibility of the optic nerve itself to light. If it be so contrived that a strong beam of light shall fall upon the bottom of the eye, so as to impinge on the end of the nerve where it begins to expand into the delicate retina, no sensation of light will be produced. This ought not to surprise us, if I am correct in my statement that the gross matter of the nerve is not the organ of vision, but the exterior surface of it only; for in the extremity of the optic nerve there is, of course, no posterior surface. Indeed, nothing can better prove the distinct office of the nerve itself, as contrasted with the expanded retina, than this circumstance,—that when a strong ray of light strikes into the nerve, the impression is not perceived: it seems to imply that the capacity of receiving the impression, and that of conveying it to the sensorium, are two distinct functions.

Is not this opinion more consistent with the phenomena, than what is expressed by one of our first philosophers,—that the nerve at its extremity towards the eye is insensible, and forms what has been called the *punctum cœcum* (blind spot), because it is not yet divided into those almost infinitely minute fibres, which he considers can alone be fine enough to be thrown into tremors by the rays of light?

Independently of this "punctum cœcum," we have to observe

that the whole scene becomes more and more obscure, and finally vanishes. Let us fix the eye on the corner of the frame of the principal picture in the room; at first, everything around the frame will be distinct; in a very little time, the impression will become weaker, objects will appear dim, and then the eye will have an almost uncontrollable desire to wander; if this be resisted, the impressions of the figures in the picture will first fade: for a time, we shall see the gilded frame alone: but this also will become faint. When we have thus far ascertained the fact, if we change the direction of the eye but ever so little, the whole scene will at once be again perfect before us.

These phenomena are consequent upon the retina being subject to exhaustion. When a coloured ray of light impinges continuously on the same part of the eye, the retina becomes less sensible to it, but more sensible to a ray of the opposite colour. When the eye is fixed upon a point, the lights, shades, and colours of objects continuing to strike upon the same relative parts of the retina, the nerve is exhausted: but when the eye shifts, there is a new exercise of the nerve: the part of the retina that was opposed to the lights is now opposed to the shades, and what was opposed to the different colours is now opposed to other colours, and the variation in the exciting cause produces a renewed sensation. From this it appears how essential the incessant searching motion of the eye is to the continued exercise of the organ.

Before dismissing this subject, we may give another instance. If we are looking upon an extensive prospect, and have the eye caught by an object at a distance, or when, in expectation of a friend, we see a figure advancing on the distant road, and we endeavour to scrutinise the object, fixing the eye intently upon it, it disappears; in our disappointment we rub the eyes, cast them about, look again, and once more we see the object. The reason of this is very obvious: the retina is exhausted, but becomes recruited by looking on the other objects of different shades and colours. The sportsman feels this a hundred times, on the moor or the hill-side, in marking down his covey, and keeping his eye fixed, while travelling towards the spot.

Reverting to the sensible part of the retina, it does not appear that we are authorised to term it a spot. The same law governs vision, whether we look to a fine point of a needle or to

an object in an extensive landscape. We look to the end of a pen, and we can rest the attention on the point upon the one side of the slit, to the exclusion of the other, just as we can select and intently survey a house or a tree. If the sensible spot were regularly defined, it must be very small: and we should be sensible of it; which we are not. The law, therefore, seems to be, at all times, that the nearer to the centre of the eye, the greater is the sensibility to impression; and that holds whether we are looking abroad on the country, or are microscopically intent upon objects very minute.

When men deny the fine adaptation of the muscular actions of the eye to the sensations on the retina, how do they account for the obvious fact—that the eye-ball does move in such just degrees? how is the one eye adjusted to the other with such marvellous precision? and how do the eyes move together in pursuit of an object, never failing to accompany it correctly, whether in tracing the flight of a bird, or the course of a tennis-ball, or even that of a bomb-shell? Is it not an irresistible conclusion, that to follow an object, and adjust the action of the muscles of the eye so as to present the axis of vision successively to it as it changes its place, we must be sensible of these motions? for how could we direct the muscles, unless we were conscious of their action? The question then comes to be—whether, being sensible of the condition of the muscles, and capable of directing them with extraordinary minuteness, the sense of the action of the muscles does not enter into our computation of the place of an object?

But is not this exactly the same question recurring, as when we asked—whether in judging of the place of an object, by the hand, we did not include, as an important part of the process of perception, the knowledge acquired through the sense of the muscular action of the arm? Must there not be a consciousness of the position of the hand, before we can direct it to an object? And must we not have a knowledge of the relation of the muscles and of the position of the axis of the eye, before we can alter its direction, to fix it upon a new object?

It surprises me to find ingenious men refusing their assent to the opinion, that the operation of the muscles of the eye is necessary to perfect vision, when they may witness the gradual acquisition of the power by the awakening sense in the infant.

When a bright object is withdrawn from the infant's eye, there is a blank expression in the features; but an excitement as soon as the object is again presented. For a time, if we shift the object before it, it is not attended with the searching action of the eye; but, by and by, the eye follows the object, and looks around for it when lost. In this gradual acquisition of power to guide the eye to the object, there is an exact parallel to the acquisition of power to seize with the hand: in both instances, the infant seeks to join the experience obtained by means of the muscular motion, with the impression on the proper nerve of sense.

Some maintain that our idea of the position of an object is implanted in the mind, and independent of experience. We must acknowledge the possibility of this, had it been so provided. We see the young of some creatures enjoying the sense of vision perfectly at the moment of birth: but in these animals, every corresponding faculty is, in the same manner, fully developed from the beginning: the dropped foal, or the lamb, rises and follows its mother. As to the property of the eye which we are considering, we can no more compare what it is in the helpless human offspring, with what it is in the young of other animals, than compare the duration of man's existence with that of the fly, which has its period of life limited to an hour at noon,—which breaks from its confinement, knows its mate, deposits its eggs on the appropriate tree, the willow or the thorn—then dies. These subjects are foreign to the inquiry; since it is obvious that the human eye has no such complete power of vision originally bestowed upon it, but that, like the exercise of the other senses, and the faculties of the mind itself, it is perfected by repeated efforts, or experience.

If it be admitted that the ideas received through the eye are acquired by experience, we must allow that before a conception can be formed of an object being exterior to the eye, or of its being placed in a particular direction, the mind must have been engaged in an act of comparison. Authors make the subject complex by referring to the inverted picture drawn at the bottom of the eye; representing to us the mind contemplating this picture, and comparing the relative position of its parts. But it is not shown how the mind looks into this camera! The question would be rendered, at least, more simple, if we asked

ourselves, how we know the direction in which any single point is seen by the eye. Suppose it is a star in the heavens, or a beacon seen by the mariner. In order to ascertain the position of the star, must he not find out some other object of comparison, some other star which shall disclose to him the constellation to which the one that he is examining belongs: or to ascertain the position of the beacon, must he not look to his compass and card, and so trace the relative direction of the light-house? This is, in fact, the process followed every time that we look at an object. A single point is directly in the axis of the eye; but we cannot judge of its position without turning to some other point, and becoming sensible of the traversing of the eye-ball and the angle to which it is moved: or if we do not see another point to compare with the first, we must judge of its place by means of a comparison with the motion of the eye itself. We are sensible that the eye is directed to the right or to the left; and we compare the visible impression on the nerve with the motion, its direction, and its extent.

Even mathematicians are found who affirm that we judge of the direction of an object, by the line in which the several rays falling upon the retina come to the eye. They forget that the rays strike a mere point of the retina; and that this point can have no direction by itself. The obliquity of the incidence of the ray cannot be estimated by means of this point alone; rays of all degrees of obliquity are converging towards it. Do not the same mathematicians, in the very first lessons of their science, require as the definition of a line, that it shall be drawn through two points at least? Where are the two points at which a ray can affect a nerve, so as to indicate the direction of the line in which it approaches the eye? The cornea, or the humours of the eye, are not sensible to the passage of the ray.* Or is this an error that has crept in from inaccurate conceptions of the anatomy? has the idea arisen from the notion that the ray passes through the thick and turbid matter of the retina, and that we can trace its course by that means?

I would ask, why is a "finder" attached to the great telescope? Is it not because the instrument magnifies in so high a degree, that the observer can see only one object, and therefore

* See a paper by Mr Alexander Shaw, who has explained this subject very happily, *Journal of the Royal Institution*, 1832.

he cannot direct it in the heavens? It is to remedy this, that a smaller telescope, possessing a less power, but commanding a wider field, is mounted upon the greater one: this "finder" the astronomer directs to the constellation, and moves from star to star, until the one which he desires to examine is in the centre of the field: by which means he adjusts the larger telescope to his object. Is this not a correct illustration of the operation of the eye? The eye is imperfectly exercised when it sees but one point: it is not in a full performance of its function, unless when it moves from one point to another, judges of the degree and the direction of that motion, and thus enables us, by comparison, to form our conclusion as to the place of the object.

A most ingenious philosopher of our time, who has opposed these views of the compound nature of the sense of vision, and maintains that the forms and relations of objects are known by the unassisted operation of the eye-ball itself—by the transmission of the rays through the humours of the eye, and by their effect upon the retina—has also affirmed, that we should know the position of objects, even were the muscles of the eye paralytic. But when I attach so much importance to the motions of the eye, I hope it has been understood that I do not neglect the movements of the body, and more especially those of the hand. In truth, the measure which we take through the motions of the eye, is in correspondence with the experience obtained through the motions of the whole frame; and without such experience, we should have no knowledge of matter, or of position, or of distance, or of form. Were the eye fixed in the head, or its muscles paralytic, we should be deprived, in a great degree, of the exercise of the organ, and lose many of the appliances necessary for its protection: but we should still be capable of comparing the visual impression with the knowledge of the movements of the body. As long as we could distinguish the right hand from the left, or raise our head to see what is above us, or stoop to see a man's foot, we should never be at a loss to form a comparison between the impression on the nerve of sight, and the experience of the body.

Against this view of the compound operation of the eye, it is argued, that if a man receive the impression of a luminous body upon his eye, so that the spectrum shall remain when the *eyelids are shut, and if he be seated upon a stool made to turn,*

and whirled round by the hand of a friend, without his own effort, the motion of the spectrum will correspond with his own rotatory motion. No doubt it will, because he is conscious of being turned round: a man cannot sit upon a stool that is turning, without an effort to keep his place, without a consciousness of being whirled; and being sensible, at the same time, that the impression is still before his eye, he will see the spectrum in that aspect to which he has been revolved.

Were I not conscious that I was right, I should feel it necessary to make some apology for arguing against the opinions of eminent men on this matter. But I conceive the explanation of the discrepancy to be, that we are influenced considerably by the different modes in which we approach the examination of such a subject. A man accustomed to observe with admiration the properties of light, and to study the effect of the humours of the eye as an optical instrument, may be blinded to those inferences which to me, from reflecting on the living endowments that belong to the organ, seem undeniable. When, instead of looking upon the eye as a mere camera, or show-box, with the picture inverted on the bottom, we determine the value of muscular activity; mark the sensations attending the balancing of the body; that fine property which we possess of adjusting the muscular frame to its various inclinations; how it is acquired in the child; how it is lost in the paralytic and drunkard: how motion and sensation are combined in the exercise of the hand; how the hand, by means of this sensibility, guides the finest instruments: when we consider how the eye and the hand correspond; how the motions of the eye, combining with the impression on the retina, become the means of measuring and estimating the place, form, and distance of objects—the sign in the eye of what is known to the hand: finally, when, by attention to the motions of the eye, we are aware of their extreme minuteness, and how we are sensible to them in the finest degree—the conviction irresistibly follows, that without the power of directing the eye, (a motion holding relation to the action of the whole body,) our finest organ of sense, which so largely contributes to the development of the powers of the mind, would lie unexercised.

THE MOTION OF THE EYE CONSIDERED IN REGARD TO THE EFFECT OF SHADE AND COLOUR IN PAINTING.

A question naturally arises whether from this part of philosophy it be possible to suggest some principles for the assistance of the painter in the disposition of shades and colours of a picture. When attempting to establish rules for that purpose, the ideas and language of the artist or amateur are certainly very vague.

We have to remark, in the first place, that the colours of objects represented in a painting differ in most essential circumstances in the effect which they produce, from those of the natural objects themselves. In nature, bodies of various colours placed together have their tints reflected from each other, and so combined: this is one mode in which the hues of nature are harmonised before they reach the eye. But the colours upon the flat surface of the canvas cannot be thus reflected and mingled. Again, the hues of natural objects are affected by the atmosphere differently from those in a picture: the rays proceeding from distant objects are softened by means of it; whereas, in a painting, from the canvas being close to the eye, the effect of the atmosphere will amount to nothing.

There is, however, another mode by which the eye is influenced in regard to colours, and it is an effect common to natural objects and to paintings. When we repeat the familiar experiment of looking steadily, and for some time, upon differently coloured spots in succession, we become aware of the remarkable effect produced on the sensibility of the retina by the impression dwelling on the nerve. As this effect is not an incidental occurrence, but is produced, more or less, whenever we exercise the eye, the nerve must be influenced to a certain degree in the same manner on looking to the different colours of a picture. It is necessary, therefore, to carry this fact with us into the inquiry; and I may offer one or two illustrations.

If we throw a silver coin upon a dark table, and fix the eye upon its centre, it will be found, when we remove the coin, that there is, for a moment, a white spot in its place, which presently becomes deep black. If we put a red wafer upon a sheet of paper, and continue to keep the eye fixed upon it, when we remove the wafer, the spot where it lay on the white paper will

appear green. If we look upon a green wafer in the same manner, and remove it, the spot will be red; if upon blue or indigo, the paper will seem yellow. These phenomena are to be explained by considering that the nerve is exhausted from the continuance of the impression, and becomes more apt to receive *the sensation of an opposite colour. All the colours of the* prism come into the eye from a surface that is white: accordingly, when we remove the coloured wafer (take that which was red) from the white paper, all these combined colours of the prism enter; but if the nerve has been exhausted by the red colour of the wafer, it will be insensible to the red rays reflected from the paper, and the effect of the rays of an opposite kind will be increased; consequently, the spot will be no longer white, nor red, but of a green colour.

Let us next observe how this exhaustion of the sensibility of the nerve produces an effect in engraving, where there is no colour, and only light and shade. Is it possible that a high tower, in a cloudless sky, can be less illuminated at the top, than at the bottom? Yet if we turn to a book of engravings, where an old steeple, or tower, is represented standing up against the clear sky, we shall find that all the higher part is dark; and the effect is picturesque and pleasing. Now, this is perfectly correct; for although the highest part of the tower be in the brightest illumination, it is not seen as if it were—it never appears so to the eye. The reason is, that on looking towards the steeple, a great part of the retina is opposed to the strong light of the sky; and when we shift the eye, to look at the particular parts of the steeple, the reflected light falls upon the retina where it is exhausted by the direct light of the sky. If we look to the top of the tower, and then drop the eye to some of the lower architectural ornaments, the effect will infallibly be, *that the upper half of the tower will appear dark; not* by contrast, as it might thoughtlessly be said, but by the nerve being somewhat exhausted of its sensibility. This, then, is the first effect that we shall remark, as arising from the searching motion of the eye, and the variety in the sensibility of the nerve.

The refreshing colours of the natural landscape are at no time so pleasing as when, reading on a journey, we turn the eye from the book to the fields and woods; the shadows are then deeper—the

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The refreshing colours of the natural landscape are at no time so pleasing as when, reading on a journey, we turn the eye from the book to the fields and woods; the shadows are then deeper—the

greens more soothing; and the whole colours softened. Reynolds observed to Sir George Beaumont that the pictures of Rubens appeared different to him, and less brilliant, on his second visit to the continent, than on his first; and the reason of the difference he discovered to be, that on the first visit he had taken notes, and on the second he had not. The alleged reason is quite equal to the effect; but I cannot help imagining that there is some incorrectness in the use of the term brilliant, unless warmth and depth of colouring is meant; for when the eye turns from the white paper to the painting, the reds and yellows must necessarily be deeper. If we look out from the window, and then turn towards a picture, the whole effect will be gone—the reflected rays from the picture will be too feeble to produce their impression; or if we look upon a sheet of paper, and then upon a picture, the tone will be deeper, and the warm tints stronger, but the lights and shades less distinct. If we place an oil painting, without the frame, upon a large sheet of paper, or against a white wall, it will appear offensively *yellow*: this is because the eye alternately, though insensibly, moves from the white paper or wall to the painting, which is of a deep tone, and consequently the browns and yellows are rendered unnaturally strong. We see the necessity of the gilt frame for such a picture, and the effect that it produces: it does not merely cut off surrounding objects, but it prepares the eye for the colours of the painting—it allows, if I may so express it, the painter to use his art more boldly, and to exaggerate the colours of nature.

Painters proceed by experiment; and in painting a portrait, they know that they can represent the features by contrast of lights and shadows, with very little colour; but such a portrait is never popular. If they are to present the likeness without much contrast of light and shade, they must raise the features by contrasts of the colours; hence the carnations are necessarily exaggerated: but all this is softened down, by throwing a piece of drapery into the picture; and the effect of this will be so striking, from its colours preparing the eye properly for receiving those of the rest of the picture, that the features, which, perhaps, before gave the idea of an inflamed countenance, will appear natural. The common resource of the painter is to *throw in a crimson* curtain, or to introduce some flower or piece of dress, that shall lead the eye, by the succession of tints, to-

wards it: and by this means the eye will be prepared to receive the otherwise exaggerated colours of the portrait: first surveying the red curtain, and then the countenance, the whole appears coloured with the modesty of nature.

Those who hang pictures do not place an historical picture, painted after the manner of the Bolognese school, with distinct and abruptly-coloured draperies, by the side of a landscape; for the colours of a landscape, to be at all consonant with nature, must be weak and reduced to a low tone, corresponding with the effect produced by the intervention of the atmosphere; its colours, therefore, would be destroyed by too powerful a contrast. It is because pictures are, for the most part, painted on different principles, that there is a difficulty of deciding which colours are best adapted for the walls of a gallery; but, generally speaking, the dark, subdued red, or morone, brings out the colours of paintings; in other words, if we look on a wall of this hue, and then turn to the picture, the prevailing green and yellow tints will appear brighter.

The word "contrast" is used without an exact comprehension of what it implies. From the illustrations that have been given, it will be seen that the effect resulting from the proper distribution of colours placed together, is produced through the motion of the eye, combined with the law to which we have been adverting, of the sensibility of the retina. When we imagine that we are comparing colours, we are really experiencing the effect of the nerve being exhausted by dwelling on one colour, and becoming more susceptible of the opposite colour. In drapery, for example, there is such a mixture of different tints reflected from it, that although one prevail, the impression may be greatly modified by what the eye has previously experienced. If the colouring of the flesh be, as the painter terms it, too "warm," it may be made "cold" by rendering the eye insensible to the red and yellow rays, and more than usually susceptible of the blue and purple rays. Every coloured ray from the flesh is transmitted to the eye; but if the eye has moved from a yellow or crimson drapery, then the rays of that kind will be lost for the moment, and the colour of the flesh will appear less warm, in consequence of the prevalence of the opposite rays of colour.

It ought to be unsatisfactory to the philosophical student to

make use of a term without knowing its full meaning: yet much has been said about contrast and harmony in painting, as resulting from the arrangement of the colours; the idea being that the colours placed together are seen at the same time, and that this gives rise to the effect of which we are all sensible; whereas it results from alternately looking at the one colour and then at the other. The subject might be pleasantly pursued, but I mean only to vindicate the importance of the motions of the eye to our enjoyment of colours, whether they be those of nature or of art.

There is another subject of some interest, namely, the effect produced upon the retina when the eye is intently fixed upon an object, and is not permitted to wander from point to point. This touches on the chiaroscuro of painting; which is not merely the managing of the lights and shadows, but the preserving of the parts of a scene subordinate to the principal object. There is something unpleasant in a picture, even to the least experienced eye, when everything is made out, when the drapery of every figure, or the carvings and ornaments, are all minutely represented: for, in nature, things are never seen in such a way. On the other hand, a picture is truly effective, and felt to be natural, when the eye is led to dwell on the principal group or principal figure with which it is the artist's intention to occupy the imagination. With fine mastery of his art, the painter heightens the colours of the chief parts in his picture, and subdues, by insensible degrees, those which are removed from the centre; and thus he represents the scene as when we look intently at anything: that is, by making the objects which are near the axis of the eye be seen distinctly—the other objects retreating, as it were, or rising out less and less distinctly, in proportion as they recede from the centre. In the one instance, the artist paints a panorama, where, on turning round, we have the several divisions of the circle presented before the eye, and the objects visible in each, appearing equally distinct: in the other, he paints a picture, which represents the objects, not as when the eye wanders from one to the other, but where it is fixed with higher interest upon some central figure, or part of the scene, and the rest falls off subordinately.

Reverting to our main argument, the proofs of beneficence in the capacities of the living frame, we look naturally to the plea-

sures received through this double property of the eye—its motion and sensibility; and we perceive that, whilst the varieties of light and shade are necessary to vision, the coloured rays are also, by their variety, suited to the higher exercise of this sense. They do not all equally illuminate objects; nor are they all equally agreeable to the eye. The yellow, pale green, or isabella colours, illuminate in the highest degree,* and are the most agreeable to the sense; and we cannot but observe, when we look out on the face of nature, whether to the country, the sea, or the sky, that these are the prevailing colours. The red ray illuminates the least, but it irritates the most; and it is this variety in the influence of these rays upon the nerve, that continues its exercise, and adds so much to our enjoyment. We have pleasure from the succession and contrast of colours, independently of that higher gratification which the mind enjoys through the influence of association.

OF EXPRESSION IN THE EYE.

In the conclusion of the volume, I took occasion to remark that natural philosophy sometimes disturbs the mind of a weak person. I recollect a student who objected to the attitude and the direction of the eyes upwards, in prayer: "For," said he, "it is unmeaning; the globe on which we stand is round, and the inhabitants in every degree, or division, of the sphere, have their eyes directed differently, diverging from the earth, and concentrated to nothing." This foolish observation may lead us once more to notice the relations between the mind, the body, and external nature.

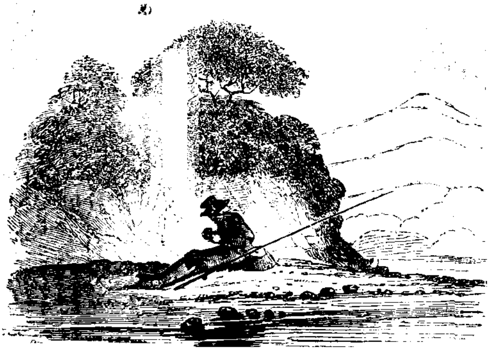
The posture, and the expression of reverence, have been universally the same in every period of life, in all stages of society, and in every clime. On first consideration, it seems merely natural that, when pious thoughts prevail, man's countenance should be turned from things earthly, to the purer objects above. But there is a link in this relation every way worthy of attention: the eye is raised, whether the canopy over us be shrouded in darkness, or display all the splendour of noon.

The muscles which move the eye-ball are powerfully affected

* The Astronomer selects for his telescope a glass which refracts the pale yellow light in the greatest proportion, because it illuminates in the highest degree and irritates the least.

in certain conditions of the mind. Independently altogether of the will, the eyes are rolled upwards during mental agony, and whilst strong emotions of reverence and piety prevail in the mind. This is a natural sign, stamped upon the human countenance, and as peculiar to man as anything which distinguishes him from the brute. The posture of the body follows necessarily, and forms one of those numerous traits of expression which hold mankind in sympathy.

The same evidence that we brought forward in treating of a somewhat similar question, on the expression of the hand, might be adduced here—the works of the great painters, who have made the sublimer passions of man the subjects of their art. By the upward direction of the eyes, and the correspondence of feature and attitude, in their paintings, they speak to all mankind. Thus we must admit that the reverential posture and uplifting of the eyes are natural, whether in the darkened chamber or under the vault of heaven. They result from the very constitution of the mind and body, and are too powerful to be effaced or altered. No sooner does pain or misfortune subdue a man, or move him to supplication, than the same universal expression prevails. Here is the correspondence of the mind, the frame, and external nature, by which man is directed to look for aid from above.



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